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NSWC/DL TECHNICAL REPORT TR-3140
November 1974

TEMPERATURE AND PRESSURE PROFILES OBTAINED DURING BURN OF A SPARROW MARK 38 MOD 0 OR MOD 1 MOTOR IN A 15,300 CUBIC-FOOT MAGAZINE, PART I

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NWL

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Deputy Technical Director

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by

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FOREWORD

The missile motor ignition tests reported herein were conducted in response to NAVSHIP Project S4643, Task 15925. This task requested that the Naval Weapons Laboratory (NWL), Dahlgren, Virginia review the need for a wet sprinkler system in missile and rocket motor stowage magazines aboard various classes of ships in view of current missile storage and handling procedures. The tests reported herein are the 3rd, 4th, and 5th of a series of seven magazines tests conducted at NWL under this project. The remaining two tests will be reported separately. NSWC/DL TR-3139 reported on the first two of these seven tests.

Data from these tests were evaluated to determine the effects of an ignition of SIDEWINDER MK 17 MOD 5 and SPARROW MK 38 MOD 0 or MOD 1 motors in a large volume magazine. Conclusions and recommendations are presented.

Released by:

J. H. MILLS, JR.
Head, Engineering Department

ABSTRACT

SPARROW MK 38 MOD 0 or MOD 1 motors were ignited in three tests in an instrumented 15,300 cubic-foot magazine under conditions that would simulate accidental ignition of the motor under shipboard service conditions using the wet or dry sprinkler system as the damage control mechanism. The results provided a detailed temperature and pressure profile in the magazine, and thermal characteristics for bare, inert, instrumented ZUNI motors, bare, inert, instrumented, all-up configuration of SIDEWINDER and ZUNI missiles, and inert, instrumented, containerized, all-up SIDEWINDER and ZUNI missiles located in the magazine.

Temperatures and pressures within the magazine reached a peak of 1200°F and 19 psig. External and internal temperatures for the instrumented, inert ordnance peaked at 915°F and 460°F, respectively. Data from these tests will assist in evaluating the relative effectiveness of the wet vs dry sprinkler system in preventing chain reaction of ordnance in deep-stowage missile magazines during motor burn, and in evaluating thermal systems designed for explosive ordnance.

CONTENTS

I. INTRODUCTION

The Navy's Improved Rearming Rates Program/Assembled Air Launched Weapons (IRRP/AALW) concept has resulted in major changes to the logistic flow of Weapons Systems. This concept provides for missiles to be brought aboard and stowed in deep stowage magazines in their respective containers. A detailed description of the IRRP/AALW concept is presented in Reference (1).

Because the containers used with the IRRP/AALW concept may delay AALW systems cook-off in deep stowage magazines, Reference (2) assigned NWL the task of obtaining data during burning of a motor in a magazine to ascertain if the containers delay cook-off of AALW systems. Under this task, a series of seven tests were conducted by NWL in an instrumented magazine which simulated a CVA deep-stowage magazine. These tests were conducted to:

(1) Provide thermal information to determine the cook-off parameters of AALW systems;

(2) Reevaluate the need for a wet (as opposed to the lighter-weight, less expensive, less complicated dry) sprinkler system in a deep stowage missile magazine;

(3) Assist in the design of more effective damage control equipment; and

(4) Provide thermal information to assist in evaluation of thermal protection systems designed for explosive ordnance.

Data from past magazine missile motor tests were not completely documented and therefore could not be referenced when needed at a later date. It is the intent of this, and subsequent reports, to document the vast amount of data obtained during the seven tests in this series.

In the first two tests, SIDEWINDER MK 17 MOD 5 motors, secured on a static thrust stand, were fired to obtain detailed temperature and pressure profiles of the simulated magazine, plus the thermal characteristics of inert, instrumented ZUNI motors located in this magazine. These data are reported in NSWC/DL Technical Report TR 3139 and were used to:

(1) Determine the size of the active motor to be used in subsequent tests; and

(2) Determine the optimum location of instrumented, inert, bare, and containerized AALW systems in the magazine for subsequent tests.

In Tests Nos. 3 through 5, SPARROW MK 38 MOD 0 or MOD 1 motors, secured on a static thrust stand, were fired to obtain detailed temperature and pressure profiles of the simulated magazine, plus the thermal characteristics of bare, inert, instrumented ZUNI motors, bare, inert, all-up configuration of SIDEWINDER and ZUNI missiles, and inert, instrumented, containerized, all-up SIDEWINDER and ZUNI missiles located in the magazine. Wet or dry sprinkler systems were used as the damage control mechanism during each test. These data were used to determine the effects of:

(1) Using a super-fast[1] activated sprinkler system;
(2) Rupture of a burning missile motor followed by deflagration; and
(3) Massive venting of the magazine

A follow-on NSWC/DL Technical Report will contain magazine test data obtained during each of the 6th and 7th tests in the series. This report will include data relative to the effects of:

(1) Using the wet sprinkler system; and
(2) Using the dry sprinkler system.

A fourth technical report will include an analysis of the collated data obtained during this program with respect to the need for a wet type magazine sprinkler system in IRRP/AALW magazines.

[1]Activated before motor burn.

II. APPROACH

Because of the high cost of hardware, materials, labor, etc., necessary to conduct magazine tests, a preliminary study was made prior to conducting any tests to:

(1) Determine if some of the tests could be combined or eliminated to reduce cost and save materials; and

(2) Insure that test sequence, instrumentation, and use of correct explosive ordnance would provide the necessary data. The test plan resulting from this study was reported by Reference (3) and served as the basis for the three tests covered in this report.

III. TEST PROCEDURES

A. Test No. 3

1. Motor: SPARROW MK 38 MOD 0

a. In Test No. 3, a SPARROW MK 38 MOD 0 motor was ignited by a black-powder igniter charge positioned near the nozzle. The test was conducted on 21 September 1973. Ambient temperature was 76°F. Prior to firing the motor, it was X-rayed to insure that no cracks or other irregularities were present that would preclude normal motor burn. The motor was provided with a pressure tap so that chamber pressure could be measured during burning.

2. Magazine Configuration

a. An NWL missile magazine was modified to simulate a large CVA-type magazine (of the AALW concept). The magazine had a volume of 15,300 cubic feet.

b. The static thrust stand was secured on the centerline of the test magazine.

c. The magazine was equipped with a blow-out patch (15 inches in diameter) set to release at 15 psig. A 20″ X 20″ steel baffle was mounted in front of the blow-out patch to prevent the dynamic pressure of the burning active motor exhaust stream from impinging on the vent.

d. The wet sprinkler system was used as the damage control mechanism. It was programmed to open the hydraulic control valve at 0.5 second after the firing pulse was applied to the active motor.

e. Four instrumented, inert ZUNI motors loaded with Filler E were located in the magazine as shown in Figure 1 of Appendix A. Temperature data similar to that resulting from short-term impingement simulating a ballistic (fly-away) rocket in the magazine was to be obtained from this configuration.

f. The location of the bare, inert, instrumented ZUNI motors, bare, inert, instrumented, all-up configuration of SIDEWINDER and ZUNI missiles, and inert, instrumented, containerized, all-up SIDEWINDER and ZUNI missiles are shown in the photograph, Figure 1 of Appendix E. The location of the latter missiles was determined from the magazine temperature and pressure profile data reported in NSWC/DL TR-3139.

3. Instrumentation

a. Fifty-two Chromel-Alumel thermocouples (illustrated in Figure 2 of Appendix A) and four strain-gage type pressure transducers were located at selected points (shown in Figure 3 of Appendix A) in the magazine to measure free air temperature and pressure in the magazine. A detailed sketch (Figure 4 of Appendix A) shows the thermocouple installation array for the test. All exterior mounted ordnance thermocouples shown in Figure 5 of Appendix A were peened to the surface of the item. The external thermocouple on the LAU 10A launcher and MK 14 MOD 0 SIDEWINDER cradle were pressed against the surface of the container and held in place with tape. All interior mounted thermocouples were mechanically pressed to bear on the inner surface wall of these ordnance items before loading the test specimen with Filler E.

b. Chamber pressure was measured on the active motor during motor burn.

c. A break-wire was installed on the blow-out patch to determine time of release if it should occur.

d. Close of firing key (CFK) and 10 KC timing was provided for time correlation.

e. Photographic coverage of the magazine instrumentation and ordnance configuration was provided for this test.

f. A micro-switch was mounted on each of two Sylphon detectors to measure the time at which the fixed temperature metal slugs melted. The Sylphon detectors were located in the ceiling of the magazine (as shown in Figure 3 of Appendix A and in the photograph, Figure 2 of Appendix E).

g. Instrumentation to detect sprinkler flow was provided.

h. Instrumentation to indicate time of the pneumatically released pilot (PRP) valve function and pressure was provided.

i. Instrumentation on the sprinkler system manifold to record activation was provided.

4. General

a. Figure 6 of Appendix A shows a block diagram of the Sprinkler Control Circuitry used in Test No. 3.

b. Figure 7 of Appendix A shows a block diagram of the Instrumentation Recording System used in Test No. 3.

c. Figure 8 of Appendix A shows a block diagram of the Pressure Data Reduction System used during Test No. 3.

B. Test No. 4

1. Motor: SPARROW MK 38 MOD 0

a. In Test No. 4, a SPARROW MK 38 MOD 0 motor was ignited by a black-powder igniter charge positioned near the motor igniter. X-ray of the motor grain before ignition was inadvertently omitted for this test. The motor was provided with a pressure tap so that chamber pressure could be measured during burning. The test was conducted on 27 September 1973. Ambient temperature was 79°F.

2. Magazine Configuration

a. The magazine configuration for this test was the same as for Test No. 3 except that a dry sprinkler system was used as the damage control mechanism. The sprinkler system was programmed to open the hydraulic control valve 15 seconds after the active motor pressure had reached 300 psig.

3. Instrumentation

a. The instrumentation for this test was the same as for Test No. 3.

4. General

a. Figure 9 of Appendix A shows a block diagram of the Sprinkler Control Circuitry used in Test No. 4.

b. The Instrument Recording System and Pressure Data Reduction System techniques (Figures 7 and 8, respectively, of Appendix A) used in Test No. 4 were the same as those used in Test No. 3.

C. Test No. 5

1. **Motor: SPARROW MK 38 MOD 1**

a. In Test No. 5, a SPARROW MK 38 MOD 1 motor was electrically ignited using the igniter installed in the motor. The test was conducted on 25 October 1973. Ambient temperature was 73°F. Prior to firing the motor, it was X-rayed to insure that no cracks or other irregularities were present that would preclude normal motor burn. The motor was provided with a pressure tap so that chamber pressure could be measured during burning.

2. **Magazine Configuration**

a. The magazine configuration for this test was the same as for Tests Nos. 3 and 4 except that the blow-out patch was set to release at approximately 18-20 psig, and the sprinkler system was programmed to open the hydraulic control valve 15 seconds after the active motor pressure had reached 300 psig.

3. **Instrumentation**

a. The instrumentation for this test was the same as for Tests Nos. 3 and 4.

4. **General**

a. Figure 10 of Appendix A shows a block diagram of the Sprinkler Control Circuitry used in Test No. 5.

b. The Instrument Recording System and Pressure Data Reduction System techniques (Figures 7 and 8, respectively, of Appendix A) used in Test No. 5 were the same as those used in Tests Nos. 3 and 4.

V. TEST RESULTS

The detailed temperature/time, pressure/time, and related instrumentation data, including photographs obtained during Tests Nos. 3, 4, and 5, are presented in Appendices B through E, respectively. The temperature curve 2-C (shown in Figure 27 of Appendix D) recorded during Test No. 5 shows an erratic drop, then rise in the temperature pattern for this thermocouple. This unusual temperature pattern may be due to erratic behavior of, and/or failure of the thermocouple. The results of these tests are given below.

A. Test No. 3

1. Figure 1 of Appendix B indicates normal motor chamber pressure and motor burn during Test No. 3. Use of a black-powder bag to initiate motor ignition resulted in a 2.80-second delay in grain ignition.

2. The pressure profile measured inside the test magazine is shown in Figures 2 through 5 of Appendix B.

3. A detailed temperature profile of the magazine (interior) was measured as shown in Figures 6 through 25 of Appendix B.

4. Exterior and interior temperature measurements were obtained on the bare, inert, instrumented ZUNI motors, bare, inert, instrumented, all-up configuration of SIDEWINDER and ZUNI missiles, and inert, instrumented, containerized, all-up SIDEWINDER and ZUNI missiles located in the magazine. These temperature curves are shown in Figures 26 through 33 of Appendix B. Figure 3 of Appendix E shows the abrasive effect of burning gases from the active motor on the No. 1 inert ZUNI motor located in the active motor exhaust stream.

5. Magazine venting occurred 4.75 seconds after CFK. Venting occurred through a 1.23 square-foot opening.

6. The metal slug in the Sylphon detector did not melt during Test No. 3.

7. Full water flow at the sprinkler heads occurred 3 seconds after CFK.

8. PRP valve actuation did not occur during this test.

9. The PRP pressure gauge failed during this test.

B. Test No. 4

1. Figure 1 of Appendix C shows that no motor pressure was recorded when the active motor ruptured. A cracked motor grain, or improper installation of the black-powder igniter charge could have caused motor rupture and deflagration following motor ignition. Figures 4 through 7 of Appendix E show the effect of motor rupture and deflagration and the extent of motor fragments spewed about the magazine.

2. The pressure profile measured by the pressure transducers inside the test magazine is shown in Figures 2 through 5 of Appendix C.

3. A detailed temperature profile of the magazine interior was measured as shown in Figures 6 through 25 of Appendix C. Propellant fragments near thermocouples caused localized high temperature inside the magazine during this test.

4. Exterior and interior temperature measurements were obtained on the bare, inert, instrumented ZUNI motors, bare, inert, instrumented, all-up configuration of SIDEWINDER and ZUNI missiles, and inert, instrumented, containerized, all-up SIDEWINDER and ZUNI missiles located in the magazine. These temperature curves are shown in Figures 26 through 33 of Appendix C.

5. The magazine did not vent during this test.

6. The metal slug in the Sylphon detector did not melt during Test No. 4.

7. Full water flow at the sprinkler heads occurred 16.5 seconds after CFK.

8. PRP valve actuation did not occur during this test.

9. A maximum of 2 psig was recorded on the detector PRP manifold.

C. Test No. 5

1. Figure 1 of Appendix D indicates normal motor chamber pressure and burn during Test No. 5.

2. The pressure profile measured inside the test magazine is shown in Figures 2 through 5 of Appendix D.

3. A detailed temperature profile of the magazine interior was measured as shown in Figures 6 through 25 of Appendix D.

4. Exterior and interior temperature measurements were obtained on the bare, inert, instrumented ZUNI motors, bare, inert, instrumented, all-up configuration of SIDEWINDER and ZUNI missiles, and inert, instrumented, containerized, all-up SIDEWINDER and ZUNI missiles located in the magazine. These temperature curves are shown in Figures 26 through 33 of Appendix D.

5. Magazine venting during Test No. 5 occurred 1.8 seconds after CFK. Venting occurred through a 21.8 square-foot opening. Figure 8 of Appendix E is a photograph of the test magazine door after the blow-out patch, 4-foot mounting ring, and plate were blown off. The mounting ring and the blow-out patch were blown several hundred feet away from the magazine. The 5/16-inch thick plate on the mounting ring was blown free and landed in front of the magazine.

6. The metal slug in the Sylphon detector did not melt during Test No. 5.

7. Full water flow at the sprinkler heads occurred 17.2 seconds after CFK.

8. PRP switch actuation occurred 1.35 seconds after CFK.

9. A maximum of 2 psig was recorded on the detector PRP manifold. The manifold pressure was 0.35 psig at the time of PRP valve activation.

VI. DISCUSSION

1. Magazine temperature and pressure profile data and external/internal temperature characteristics of bare, inert, instrumented ZUNI motors, bare, inert, instrumented, all-up configuration of SIDEWINDER and ZUNI missiles, and inert, instrumented, containerized, all-up SIDEWINDER and ZUNI missiles were obtained during Tests Nos. 3 through 5. These profiles provided thermal/time and pressure/time data for the ordnance items. These data will be used in a computer simulation study to determine cook-off parameters for explosive ordnance items while using the wet or dry sprinkler system as the damage control mechanism.

2. During Test No. 3, full water flow at the sprinkler heads occurred 3 seconds after CFK (before the SPARROW MK 38 MOD 0 motor burnout occurred). Temperature and pressure within the magazine reached a peak of 750°F and 9.7 psig. The two external thermocouples peened to the surface of the inert No. 1 ZUNI motor (located in the exhaust plume of the active SPARROW MK 38 motor) recorded peak temperatures of 725°F and 425°F, then failed. The corresponding internal thermocouples recorded peak temperatures of 350°F and 325°F, respectively. All remaining external and internal thermocouples for the Nos. 2, 3, and 4 inert ZUNI motors peaked under 200°F. All remaining thermocouples attached to the inert IRRP/AALW systems located in the magazine peaked under 150°F.

3. During Test No. 4, the active SPARROW MK 38 MOD 0 motor ruptured and deflagrated after ignition. The cause of the rupture could not be determined. Either a defective (cracked) motor grain, or improper installation of the black-powder ignition charge could have caused a pressure sufficiently high to fracture the motor grain causing rupture of the motor. Temperature and pressure within the magazine reached a peak of 1050°F and 8.2 psig. The two external thermocouples peened to the surface of the inert No. 1 ZUNI motor (located in the active motor exhaust plume) recorded peak temperatures of 395°F and 190°F. The thermocouple that recorded a temperature of 395°F was located adjacent to a large fragment of burning propellant ejected by the motor. Corresponding internal thermocouples recorded a peak temperature of 90°F. All remaining external and internal inert ZUNI motor thermocouples peaked under 160°F. All remaining thermocouples attached to the inert IRRP/AALW systems located in the magazine peaked under 250°F.

4. During Test No. 5, massive venting of the magazine occurred due to failure of the magazine mounting ring and plate mounting bolts. Temperature and pressure within the magazine reached a peak of 1150°F and 19 psig. The two external thermocouples peened to the surface of the inert No. 1 ZUNI motor

(located in the active motor exhaust plume) peaked off scale (1200°F+). The corresponding internal thermocouples recorded peak temperatures of 450°F and 350°F, respectively. The No. 2 inert ZUNI motor external thermocouples peaked at 910°F and 250°F. The corresponding internal thermocouples for inert ZUNI motor No. 2 peaked under 150°F. The No. 3 inert ZUNI motor external thermocouples peaked at 220°F and 419°F. The corresponding internal thermocouples for the inert ZUNI motor No. 3 peaked under 125°F. The No. 4 inert ZUNI motor external thermocouples peaked at 360°F and 275°F. The corresponding internal thermocouples for inert ZUNI motor No. 4 peaked under 110°F. All remaining thermocouples attached to the inert IRRP/AALW systems located in the magazine peaked under 200°F.

VII. CONCLUSIONS

The temperature/time and pressure/time profile data obtained during Tests Nos. 3, 4, and 5 are vitally important because they include the effects of:

1. A "super-fast" actuated sprinkler system as used in Test No. 3;
2. Rupture of a burning missile motor followed by deflagration as occurred in Test No. 4; and
3. Massive venting of the magazine as occurred in Test No. 5.

Knowledge of these effects is now available for use in computerized simulation programs to determine the cook-off parameters of IRRP/AALW systems, in reevaluating the need for a wet vs. dry sprinkler system in deep stowage missile magazines, and in evaluating thermal systems designed for ordnance.

REFERENCES

1. NAVAIR 11-120-27, Guidance Pamphlet, Assembled Air Launched Weapons Implementation Improved Rearming Rates Project, 1 June 1969

2. NAVSHIP Project S4643, Task 15925

3. NWL ltr EST:FJH:ddw 8000 dtd 8 March 1973

APPENDIX A

TEST MAGAZINE CONFIGURATION AND INSTRUMENTATION FOR TESTS NO. 3, NO. 4 AND NO. 5

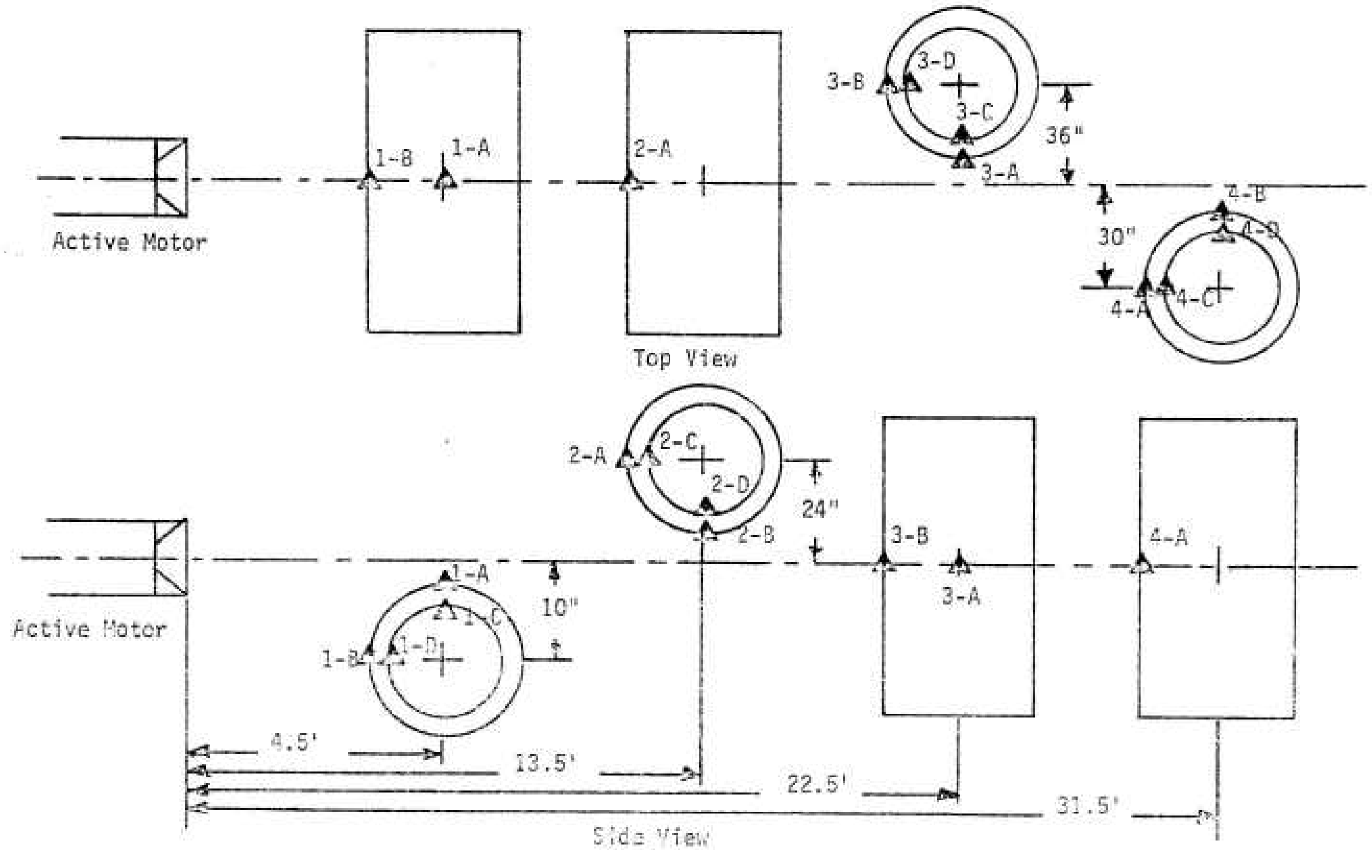


FIGURE A-1

ZUNI Motors in Exhaust Plume

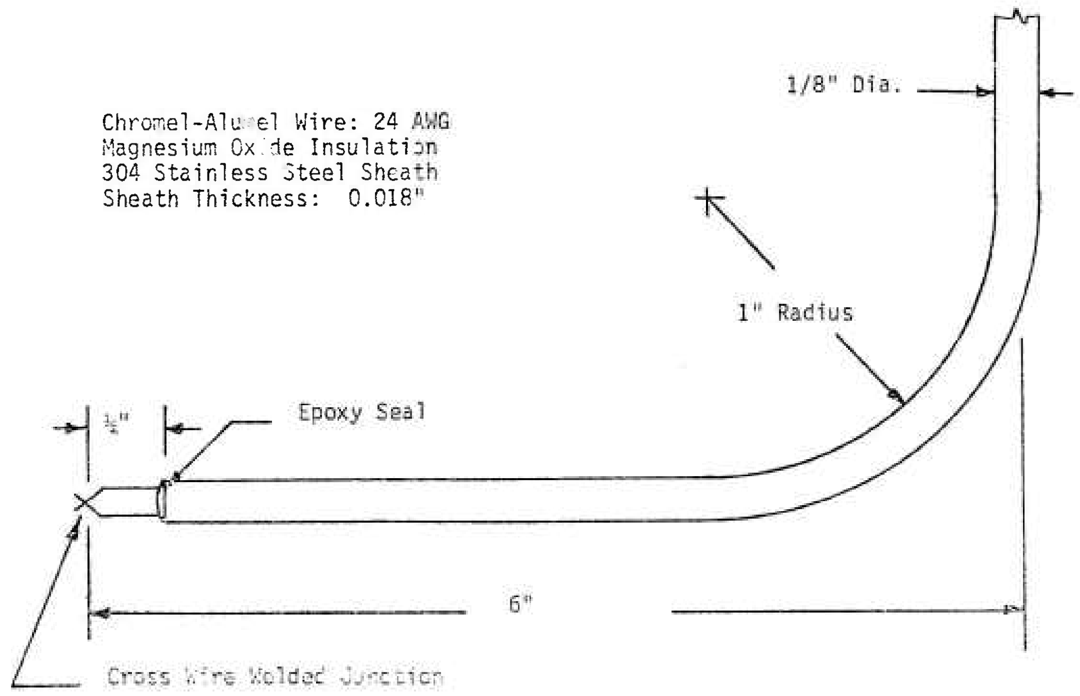


FIGURE A-2

Thermocouple Detail

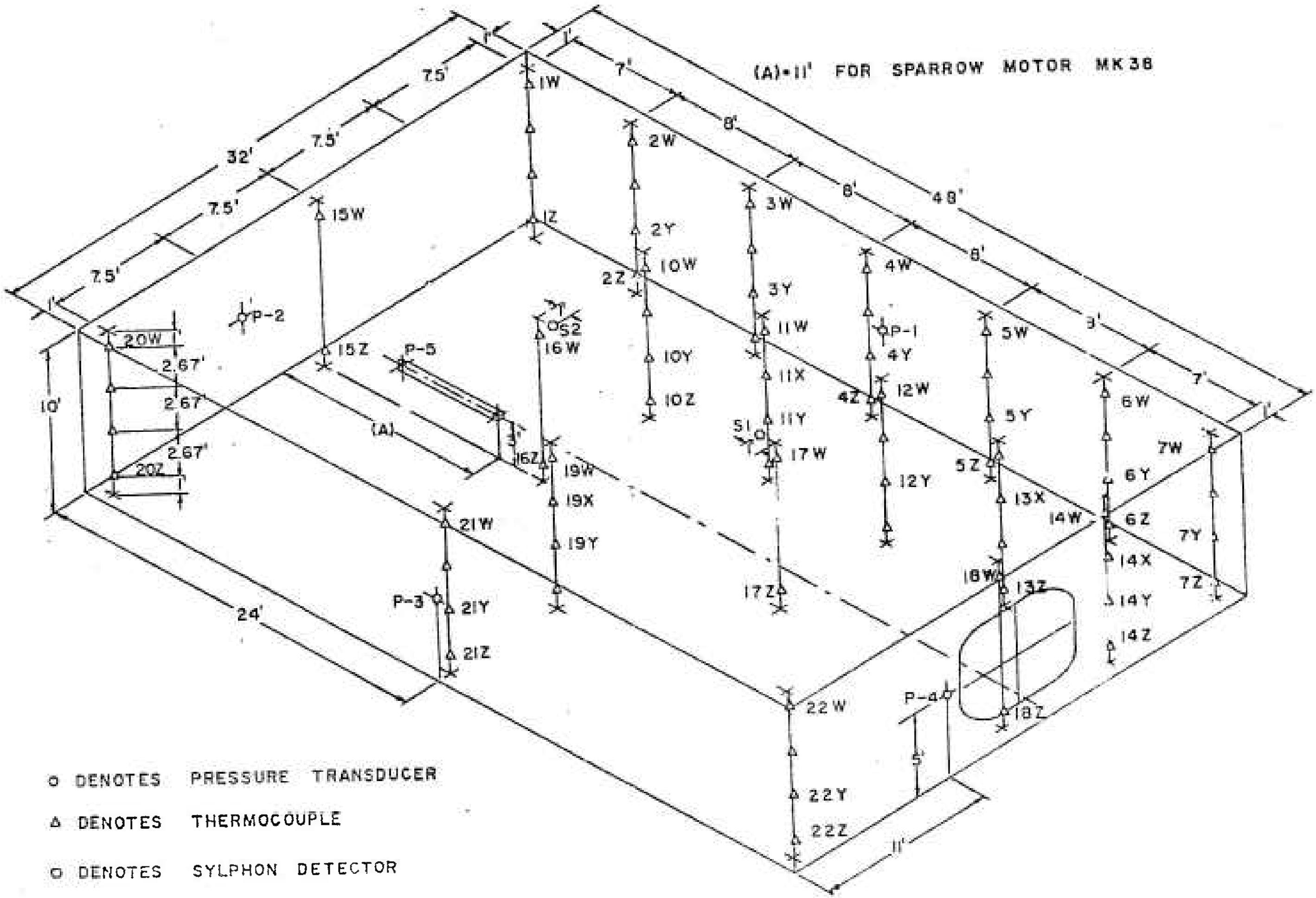


FIGURE A-3

Magazine Instrumentation Configuration
Tests Nos. 3, 4, 5

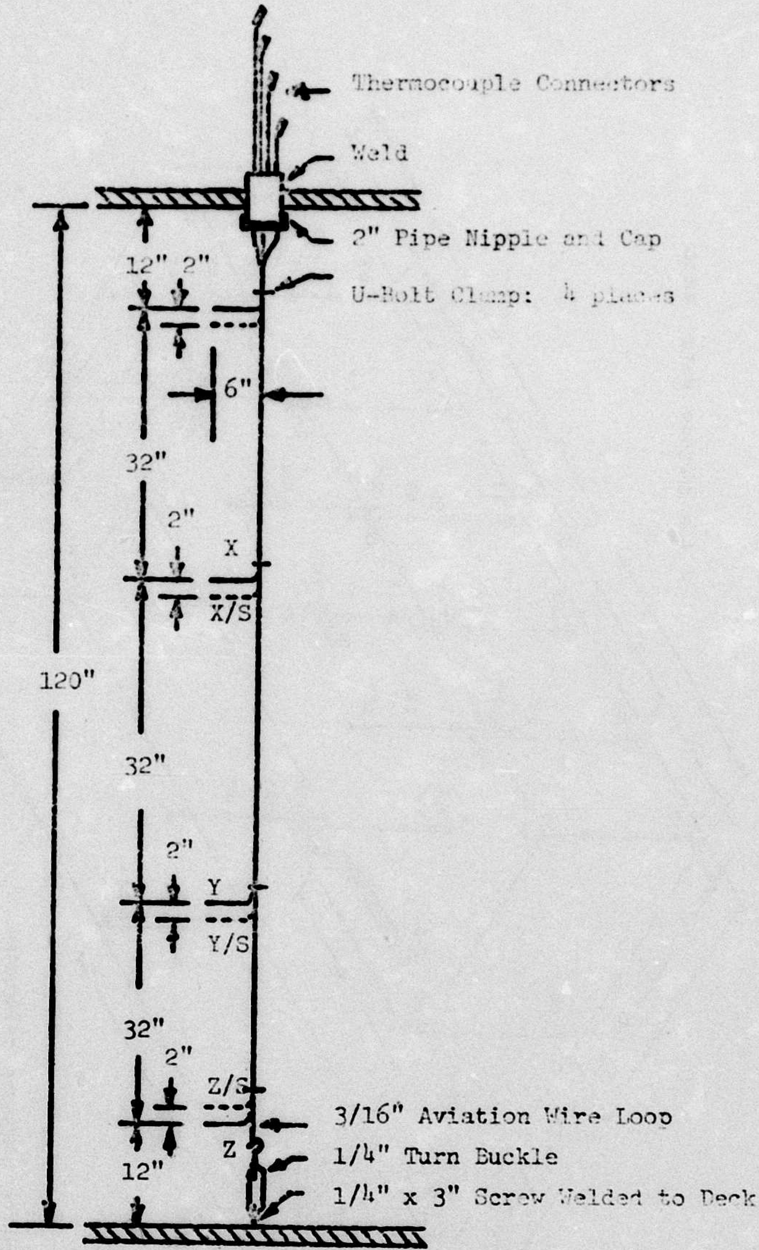


FIGURE A-4

Thermocouple Array

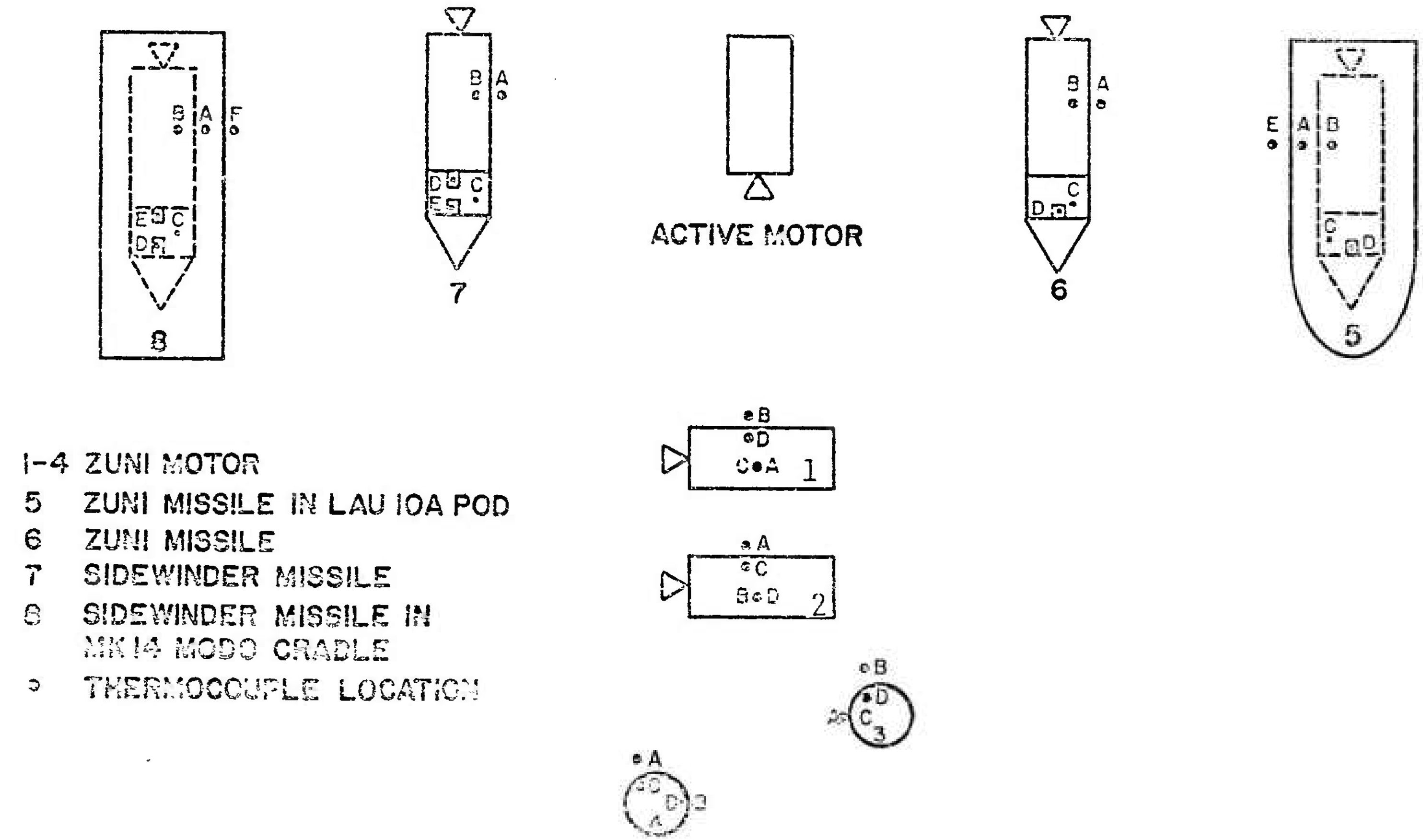


FIGURE A-5

ZUNI Motors and IRRP/AALW Systems Location in Magazine

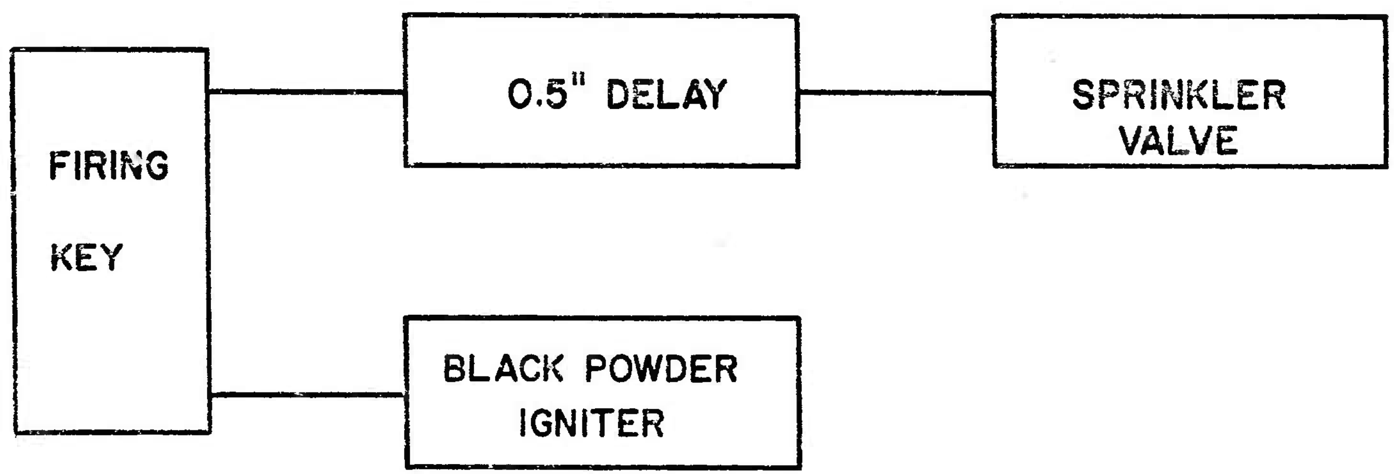


FIGURE A-6

Block Diagram of Sprinkler Control Circuitry

Test No. 3

21 Sept 1973

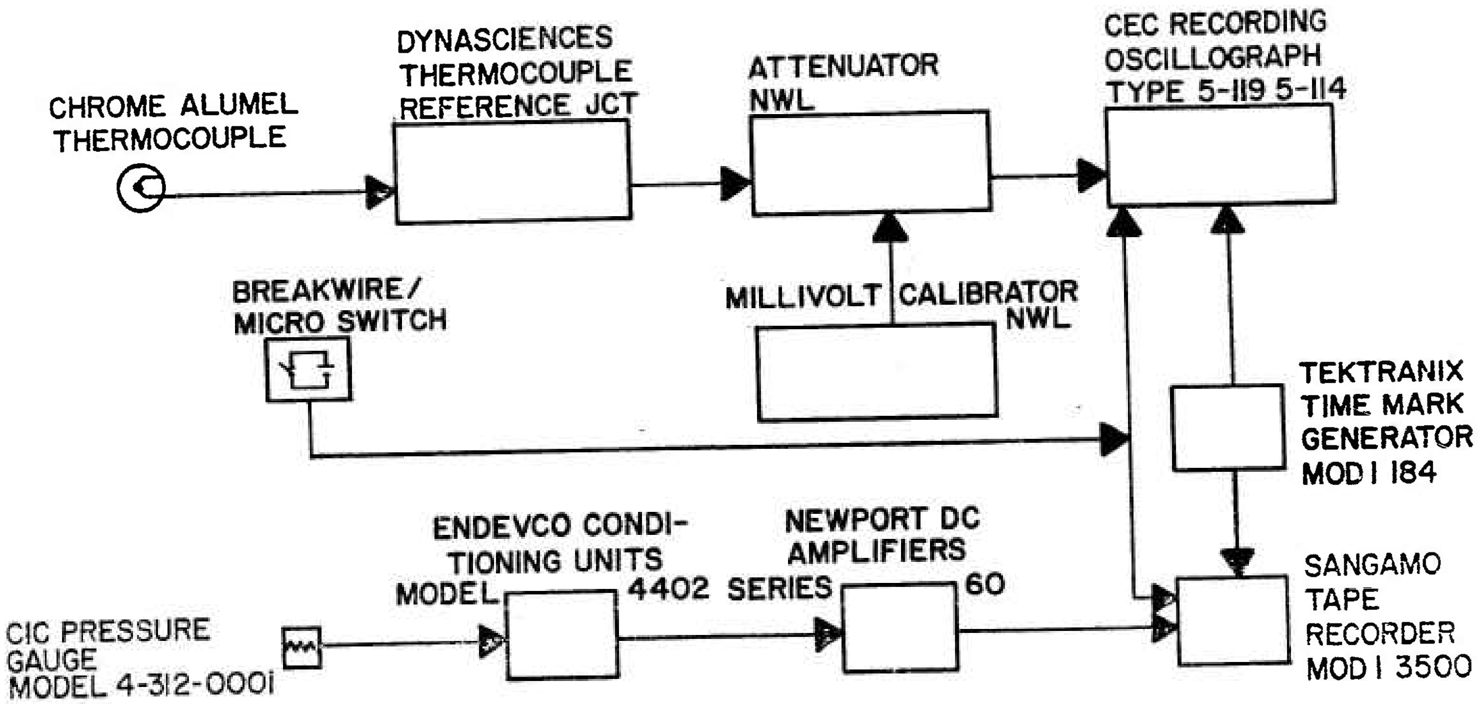


FIGURE A-7

Instrument Recording System

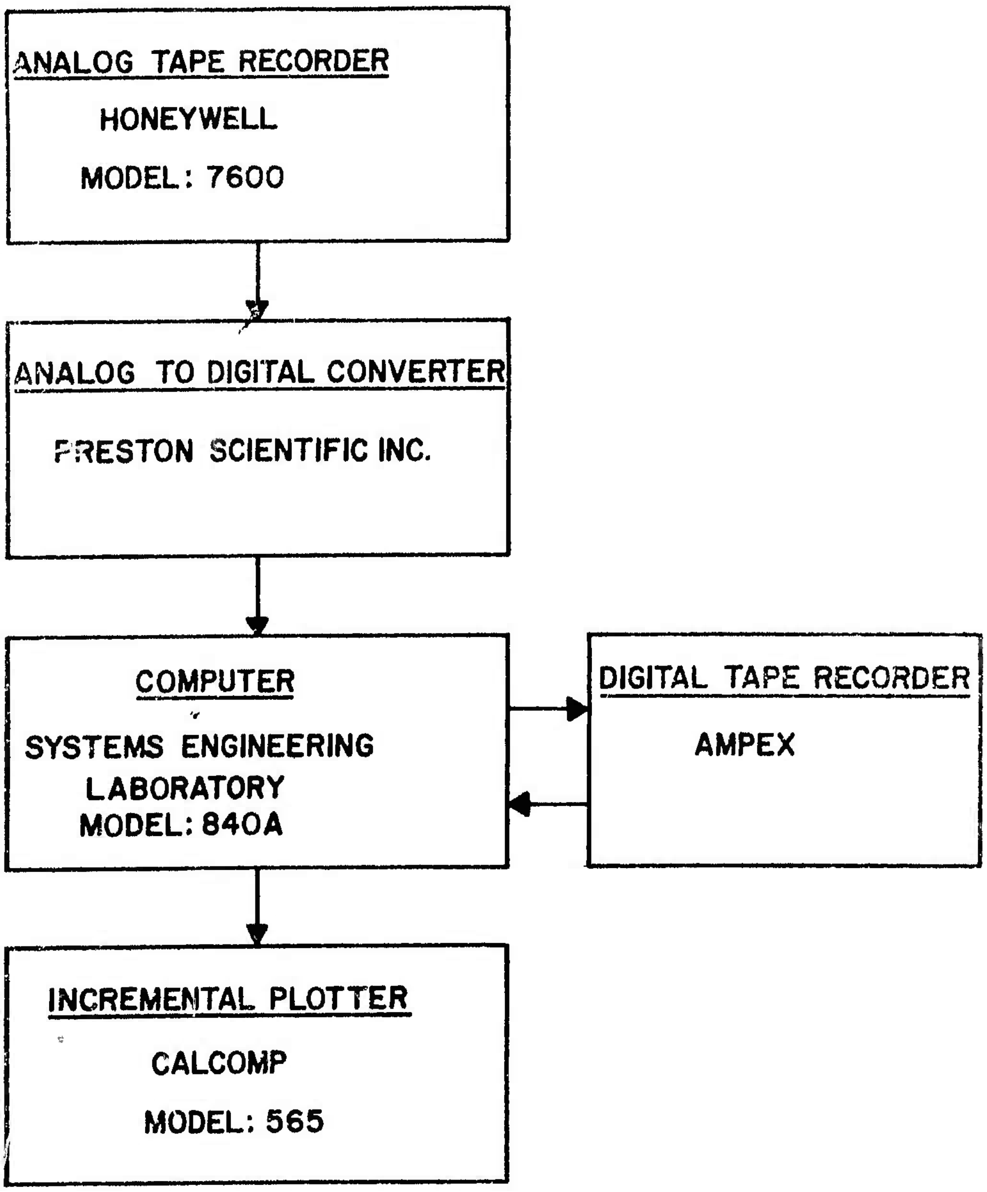


FIGURE A-8

Pressure Data Reduction System

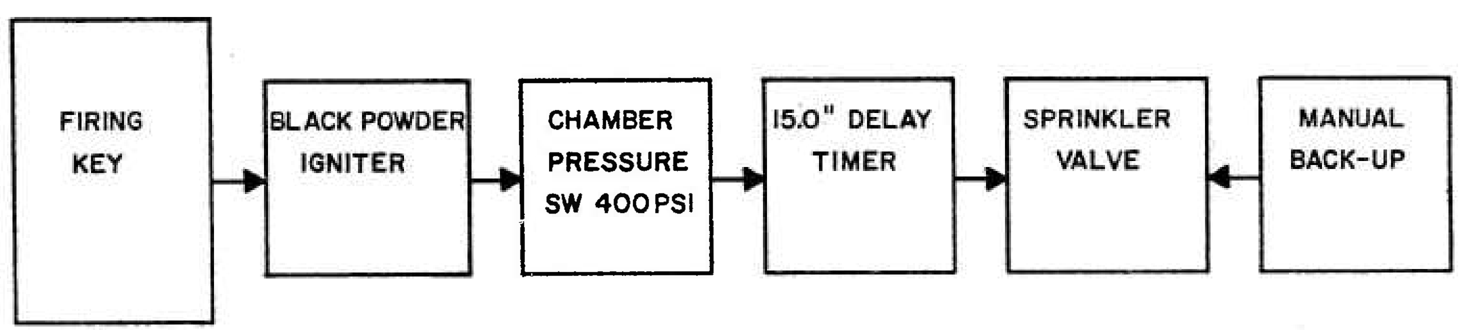


FIGURE A-9

Block Diagram of Sprinkler Control Circuitry

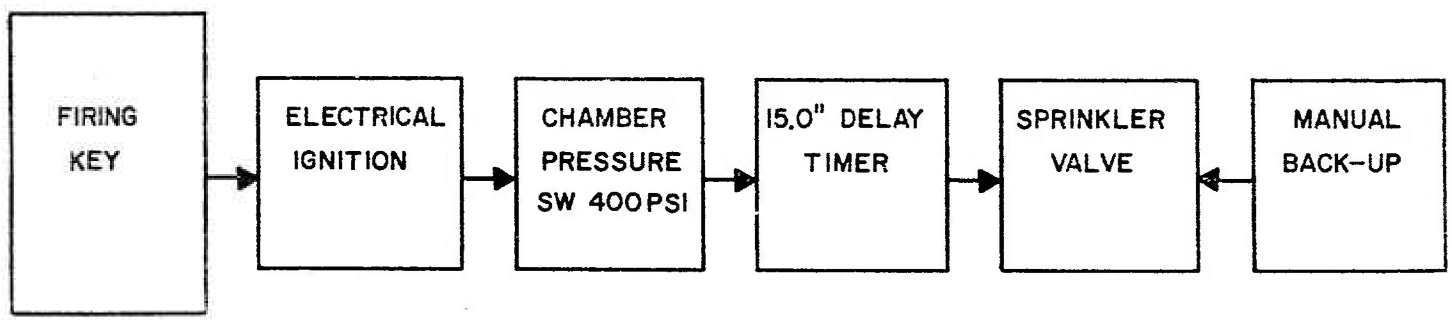


FIGURE A-10

Block Diagram of Sprinkler Control Circuitry

Test No. 5 25 October 1973

APPENDIX B

TEST DATA OBTAINED DURING TEST NO. 3

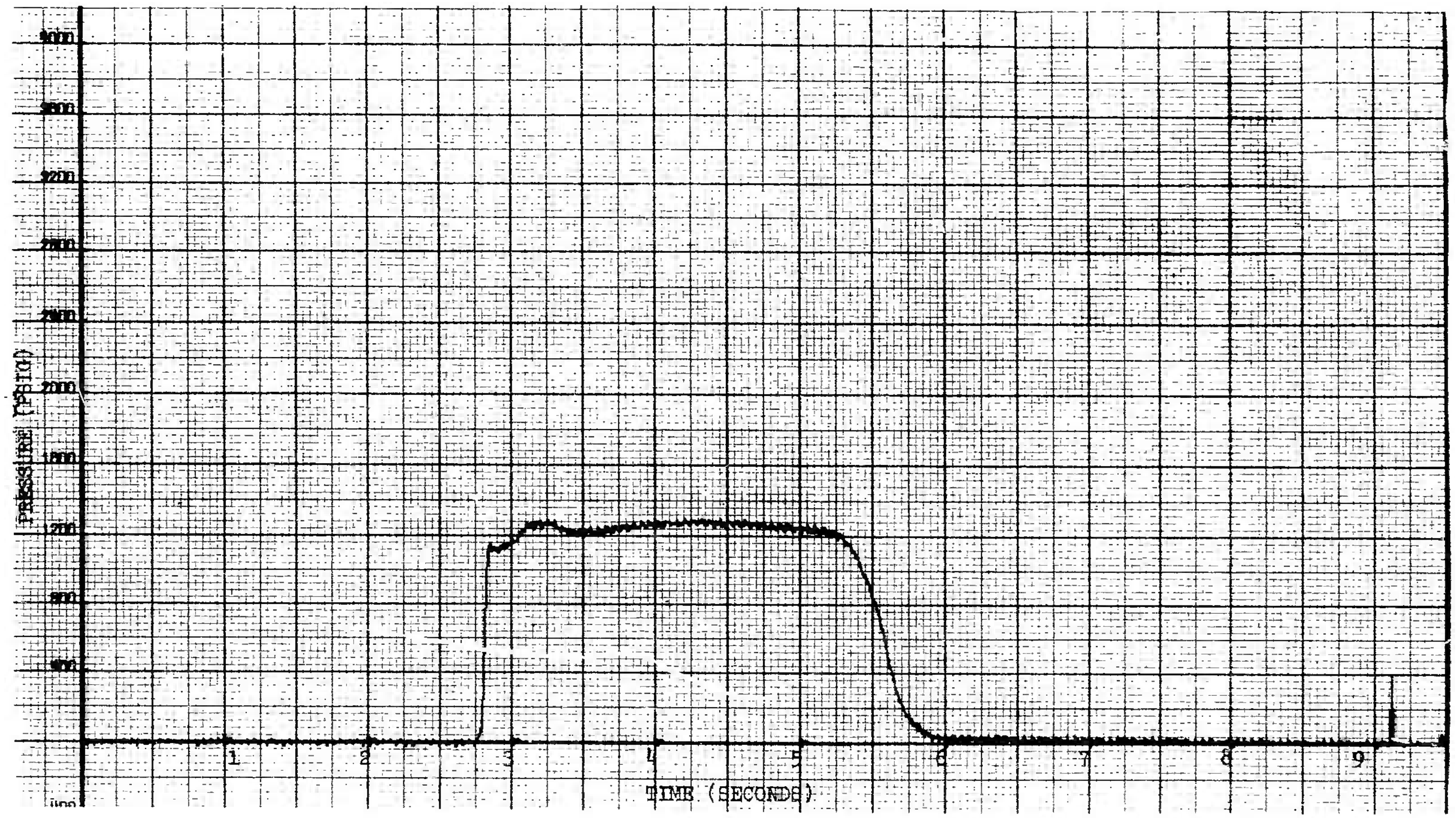
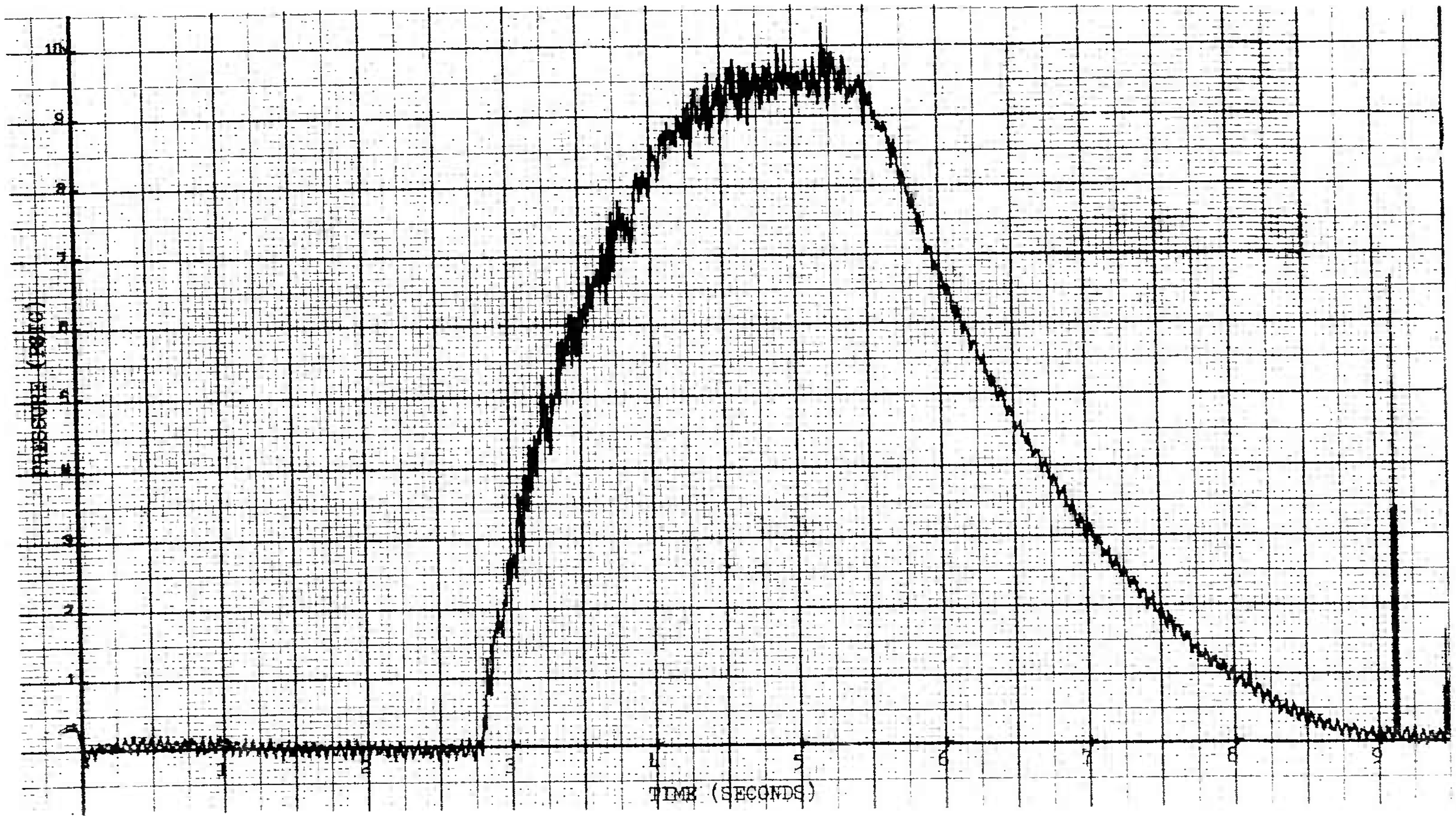
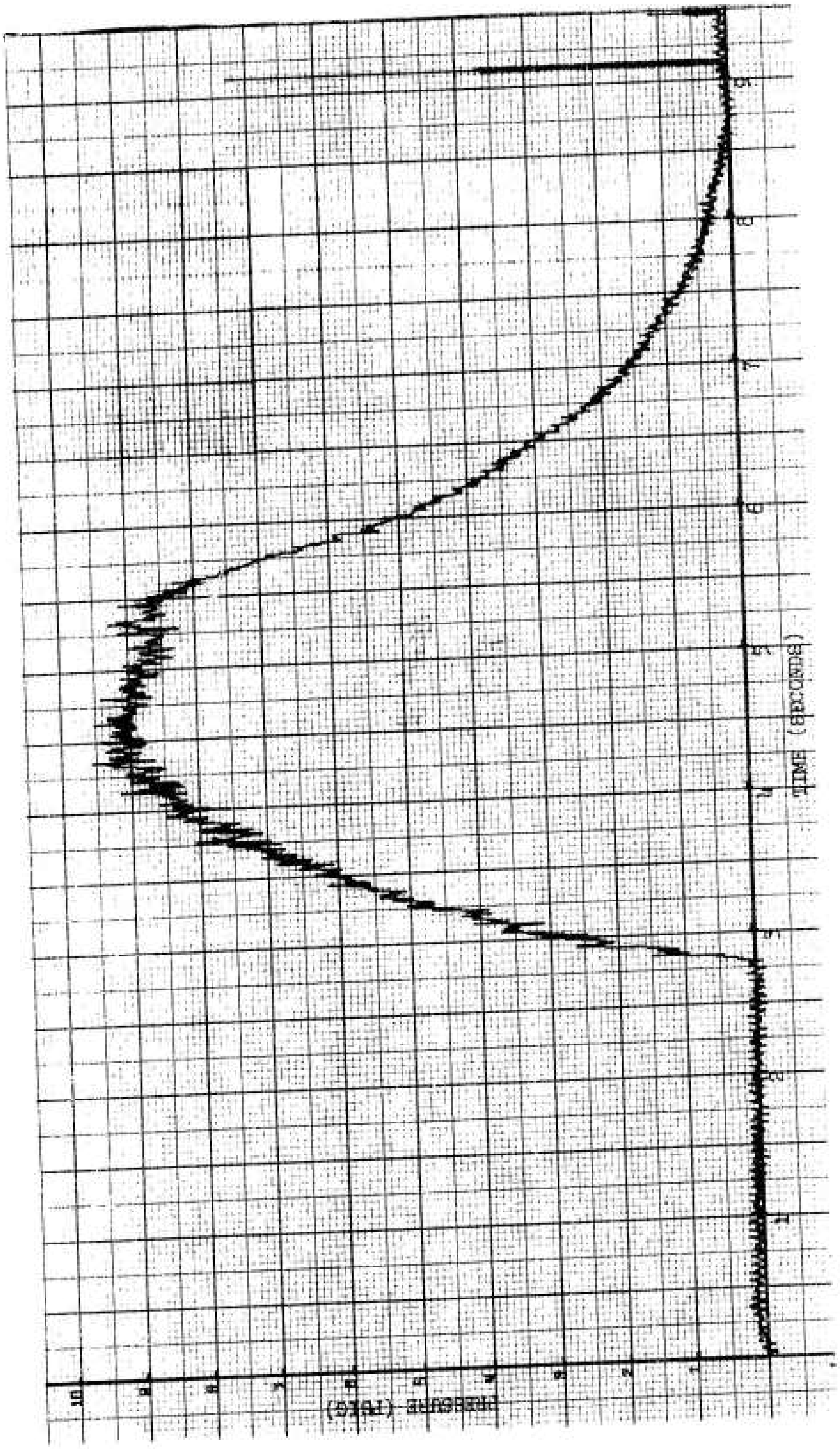


FIGURE B-1

SPARROW MK 38 MOD 0 Motor Pressure
Test No. 3



Pressure Transducer No. 1
Test No. 3



Pressure Transducer No. 2
Test No. 3

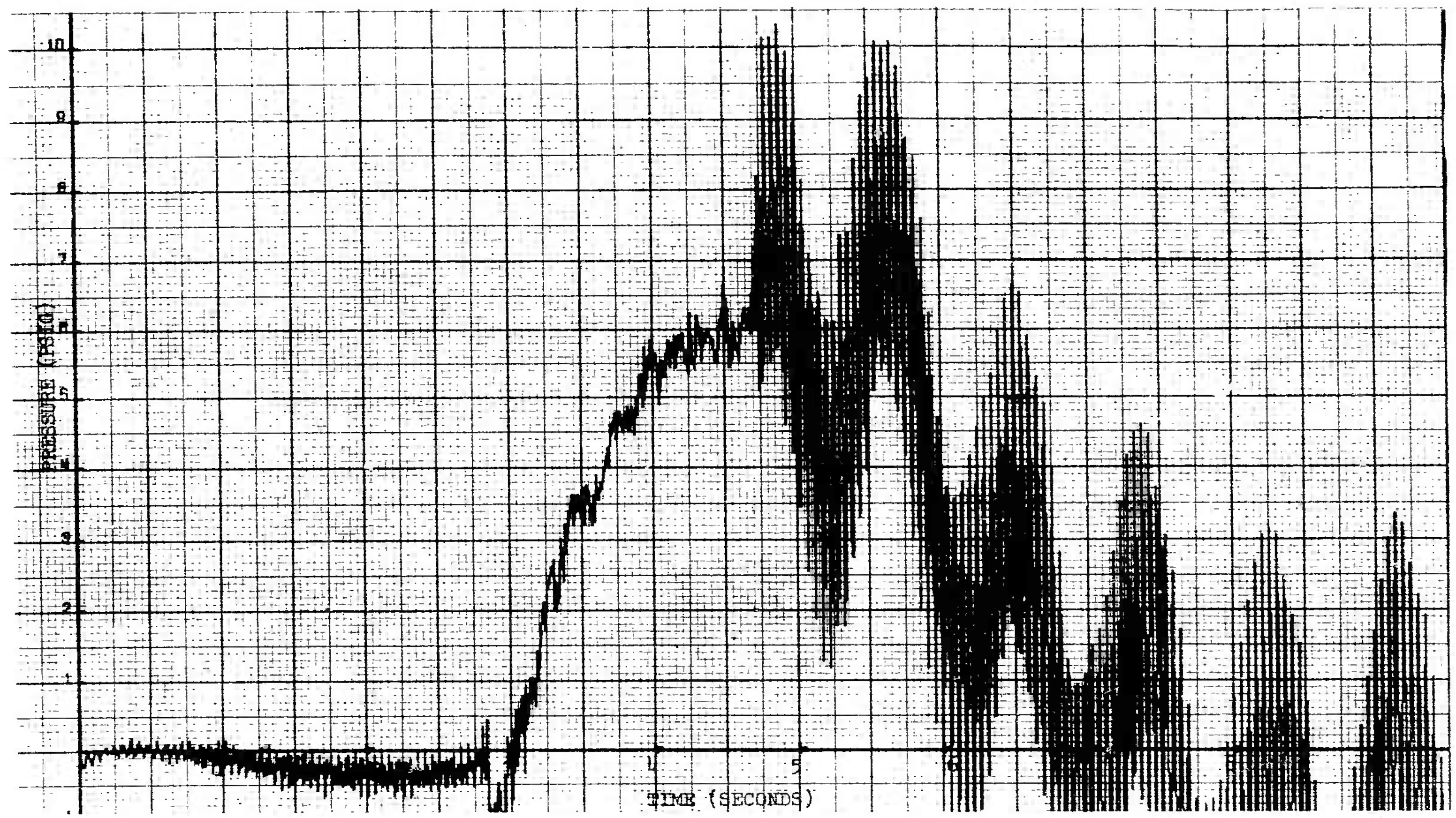


FIGURE B-4

Pressure Transducer No. 3
Test No. 3

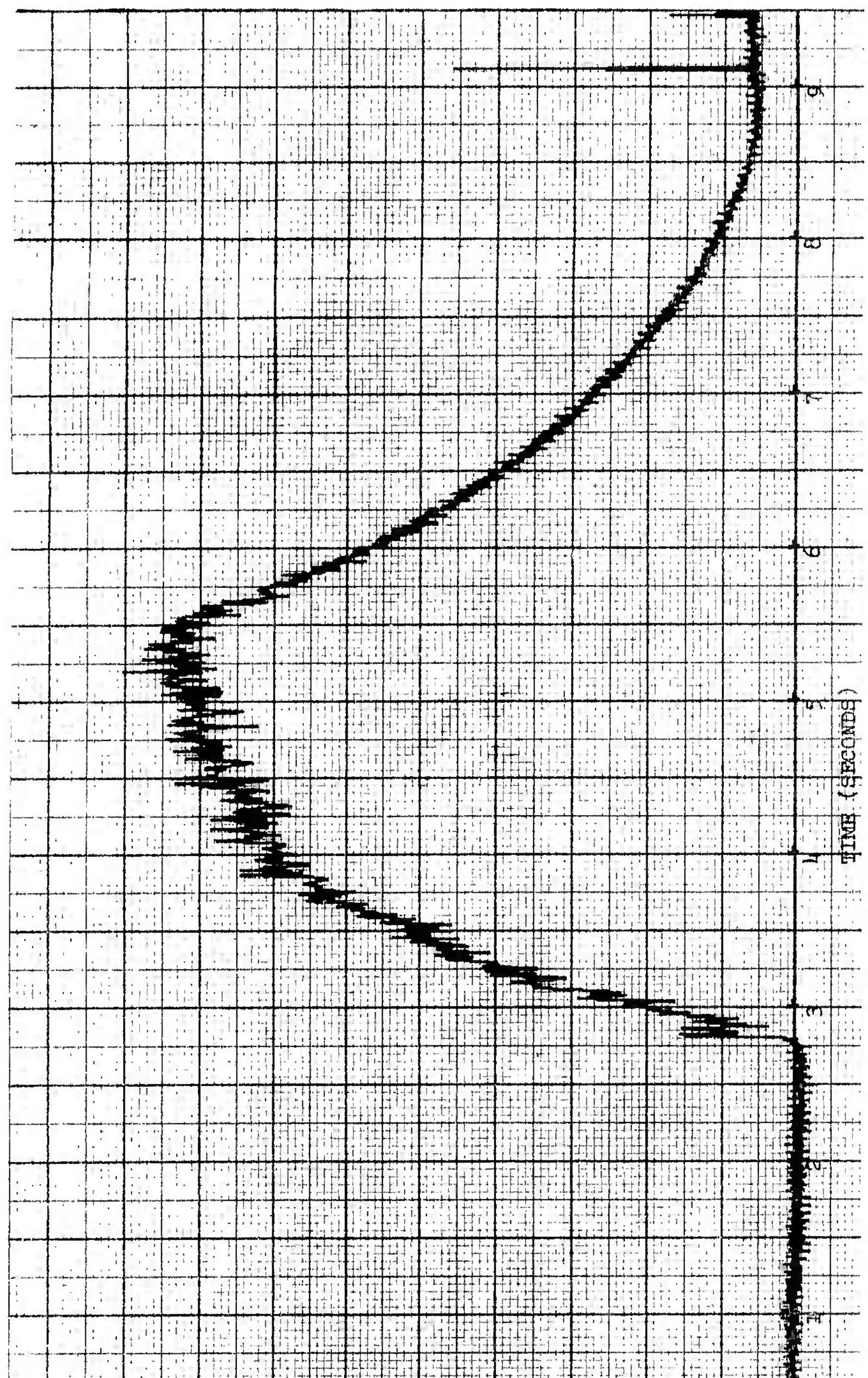


FIGURE B-5

Pressure Transducer No. 4
Test No. 3

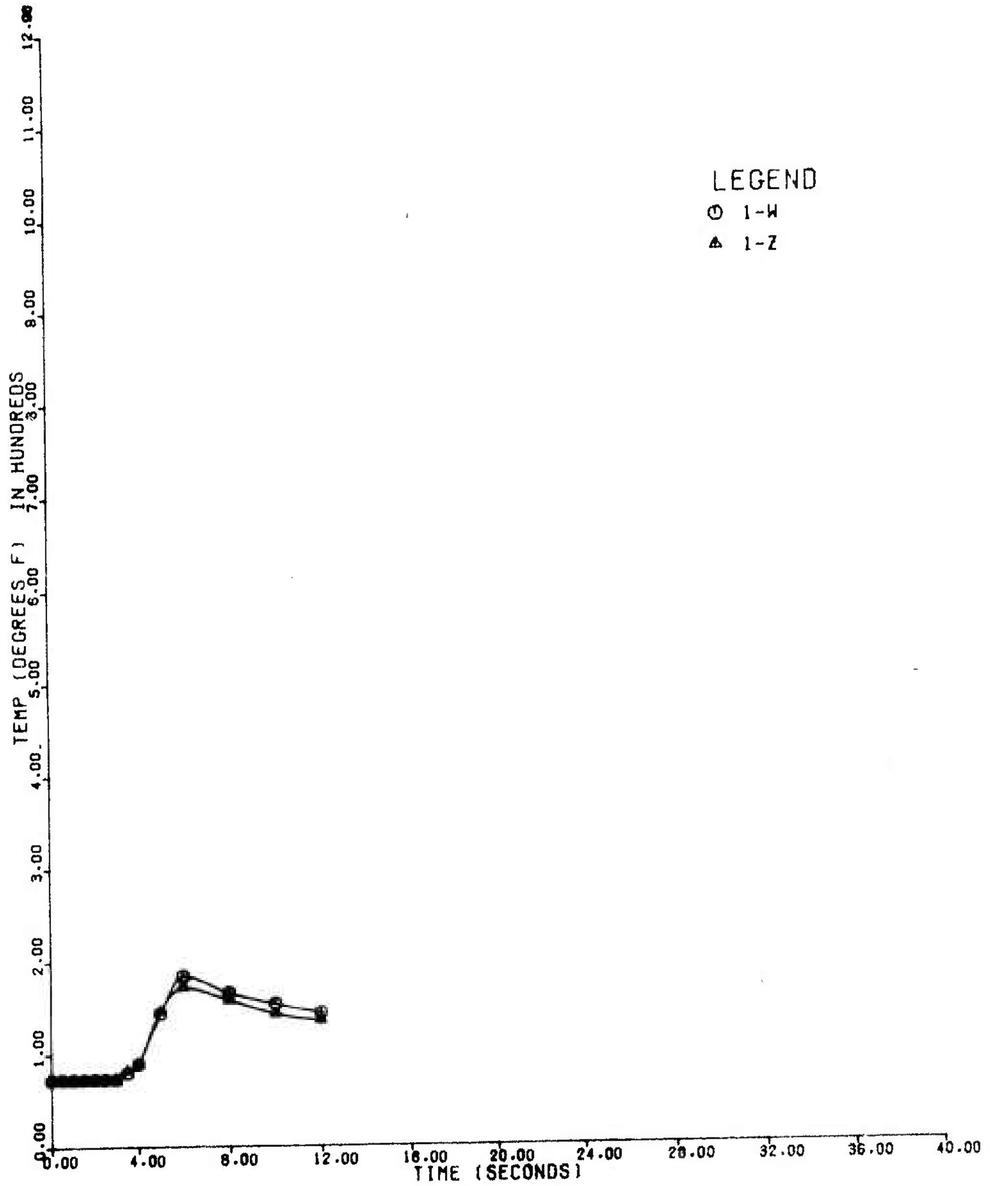


FIGURE B-6

CVA Magazine Test

No. 3 18 September 1973

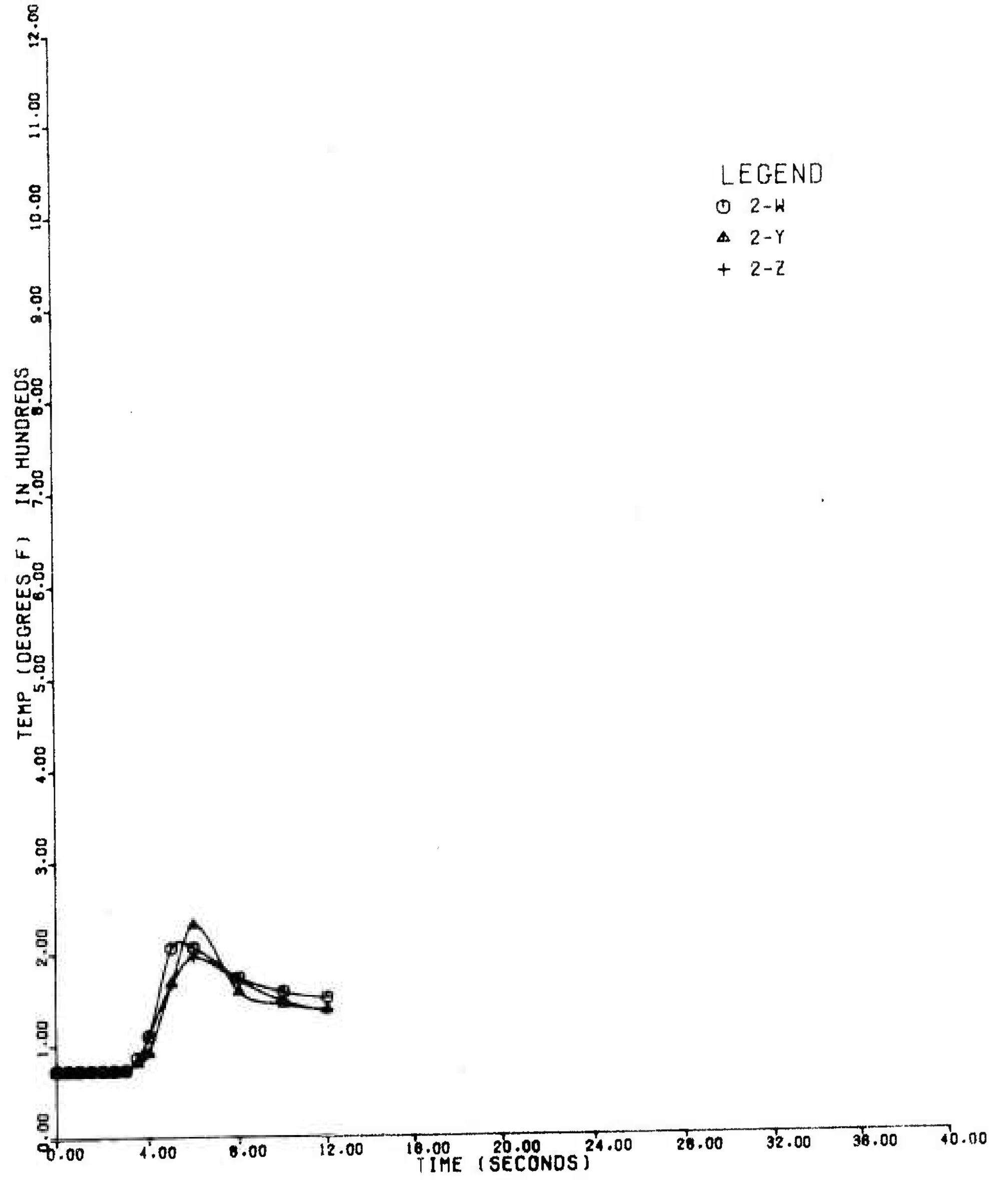


FIGURE B-7

CVA Magazine Test

No. 3 18 September 1973

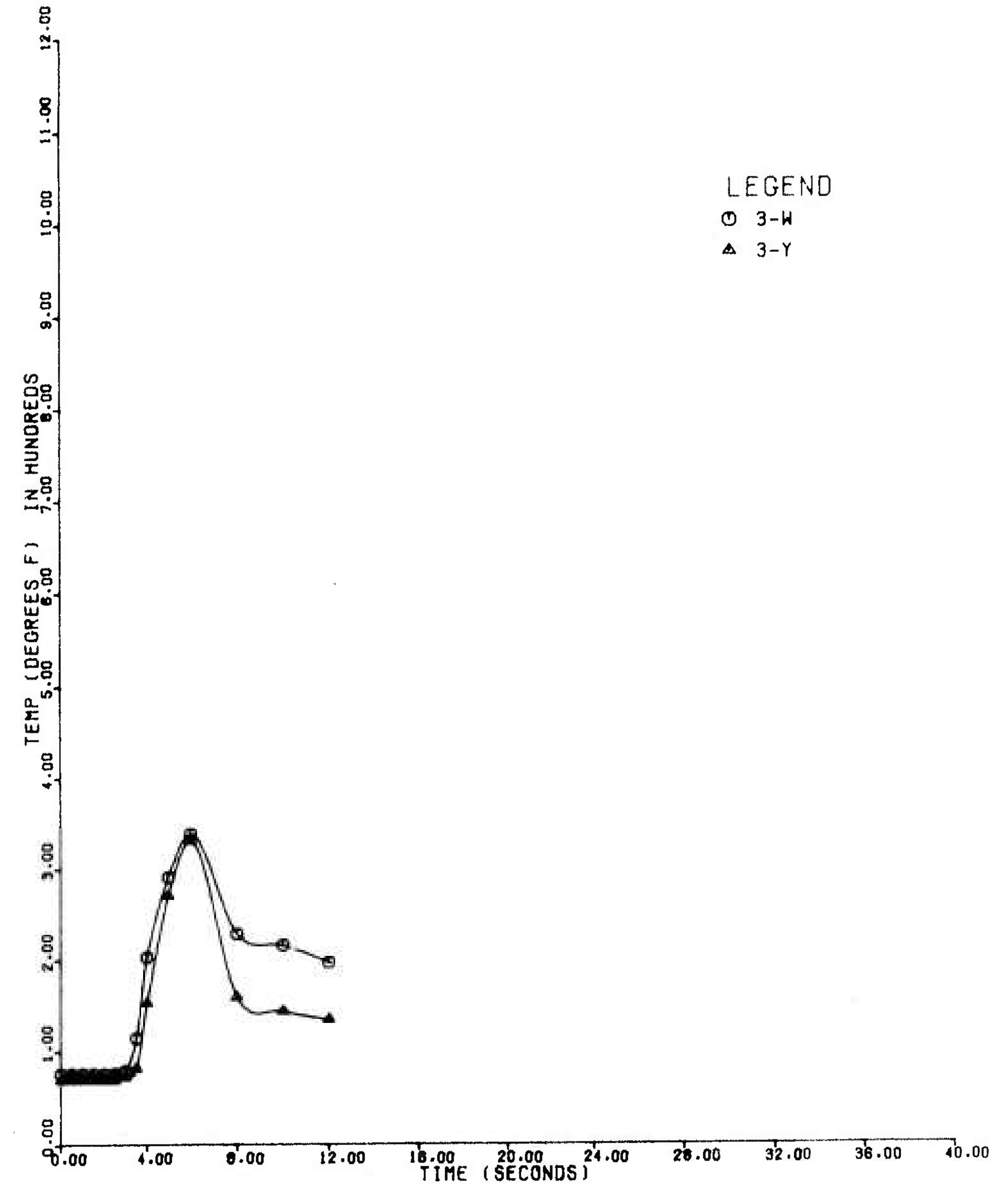


FIGURE B-8

CVA Magazine Test

No. 3 **18 September 1973**

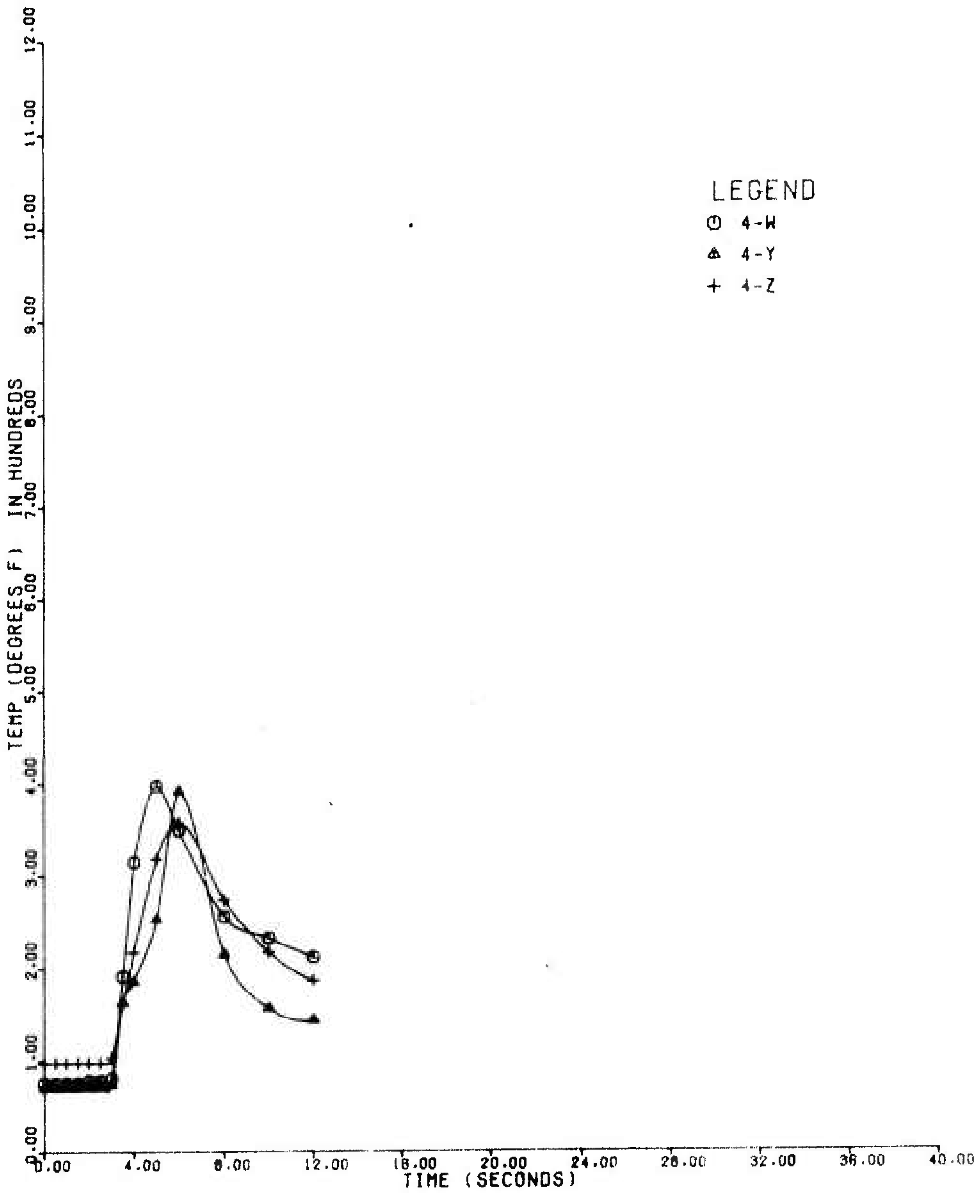


FIGURE B-9

CVA Magazine Test

No. 3 **18 September 1973**

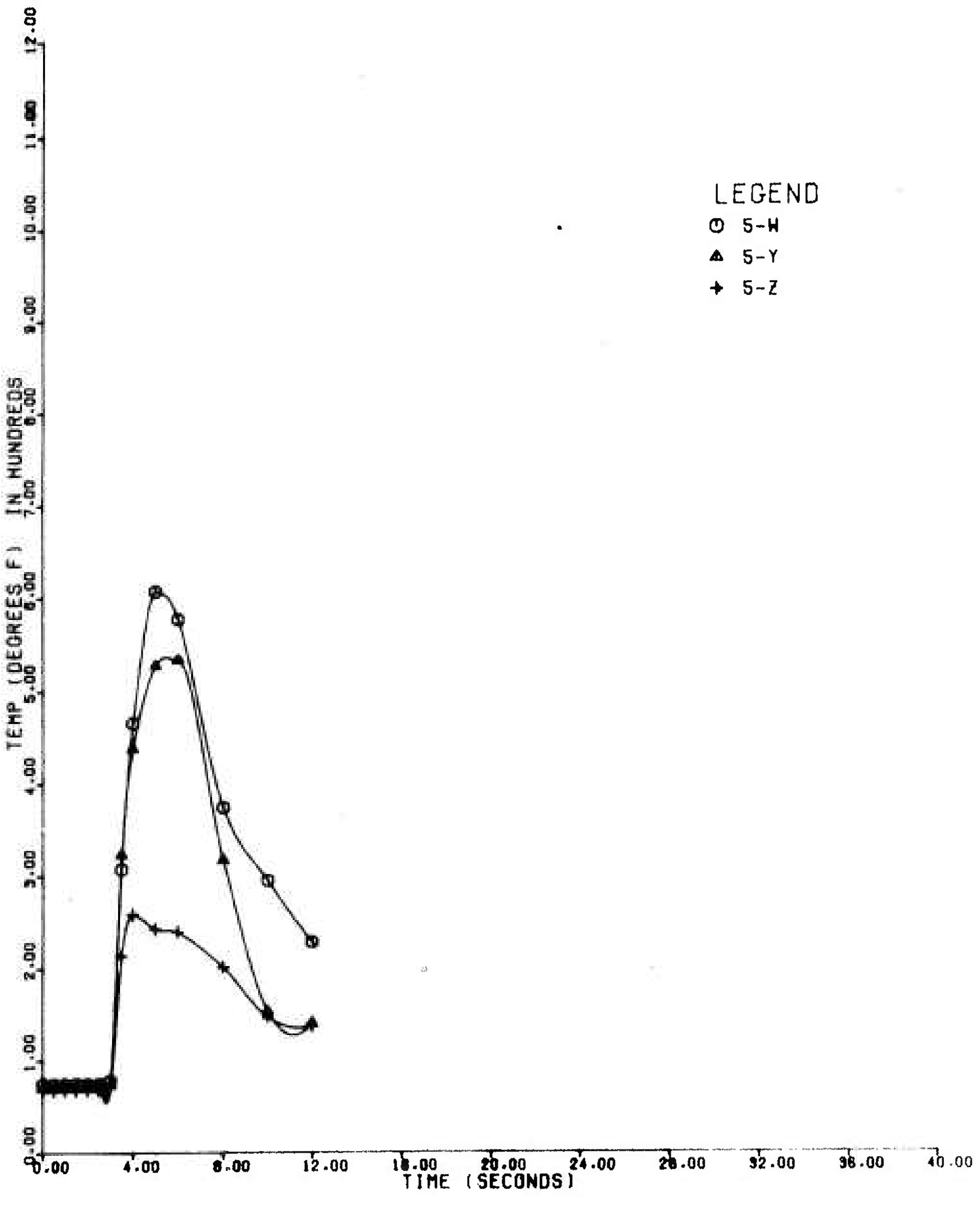


FIGURE B-10

CVA Magazine Test

No. 3 18 September 1973

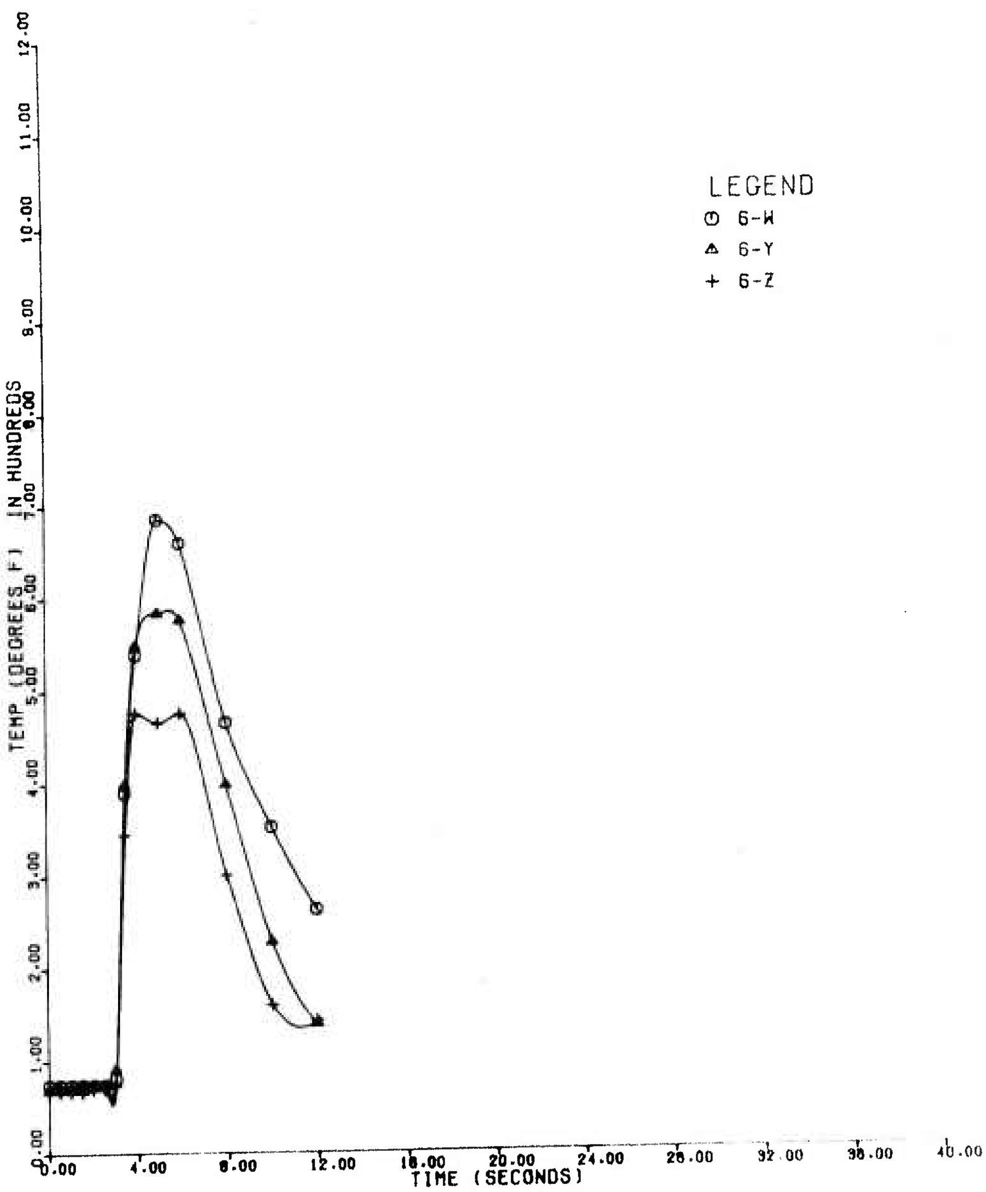


FIGURE B-11

CVA Magazine Test

No. 3

18 September 1973

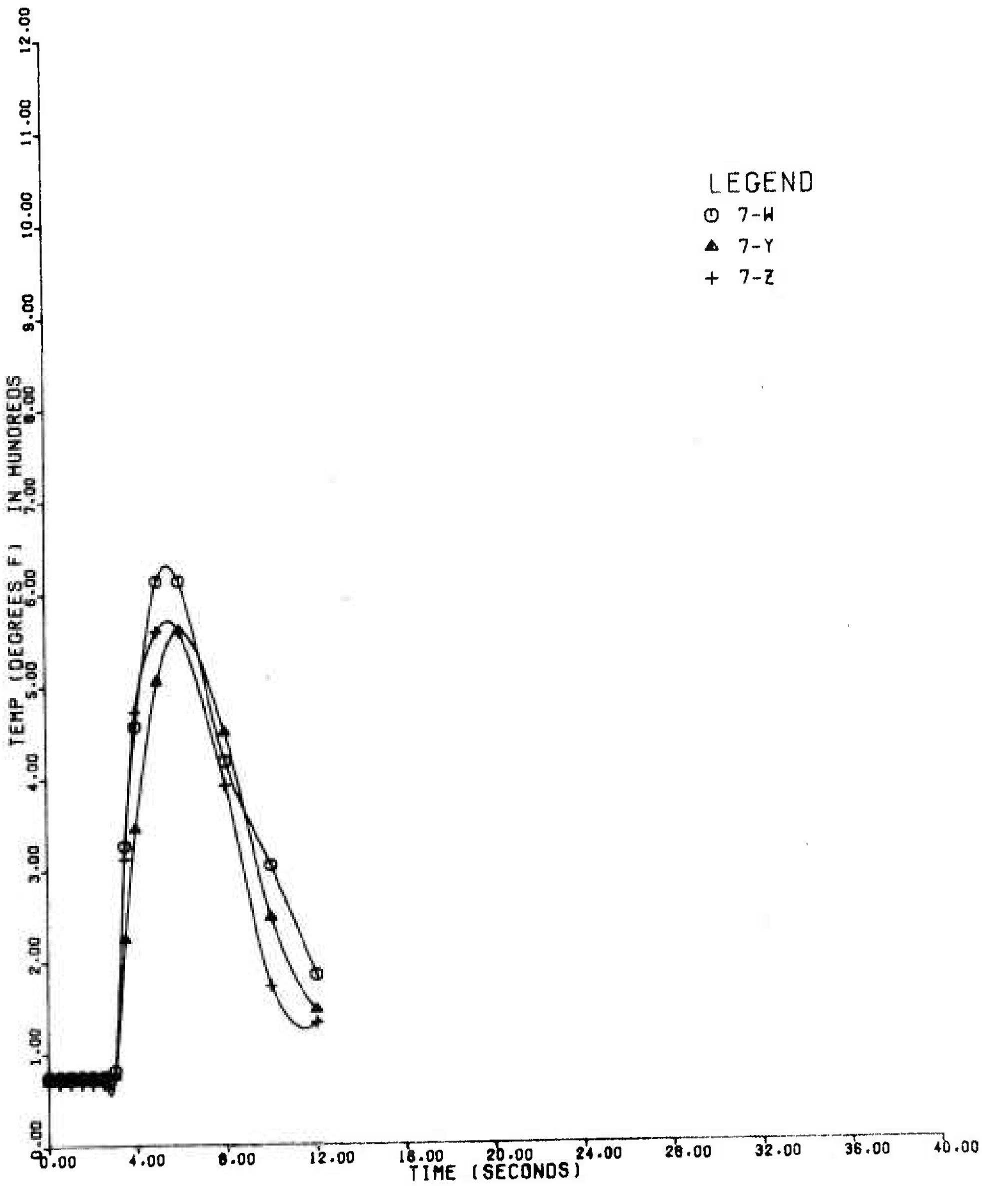


FIGURE B-12

CVA Magazine Test

No. 3

18 September 1973

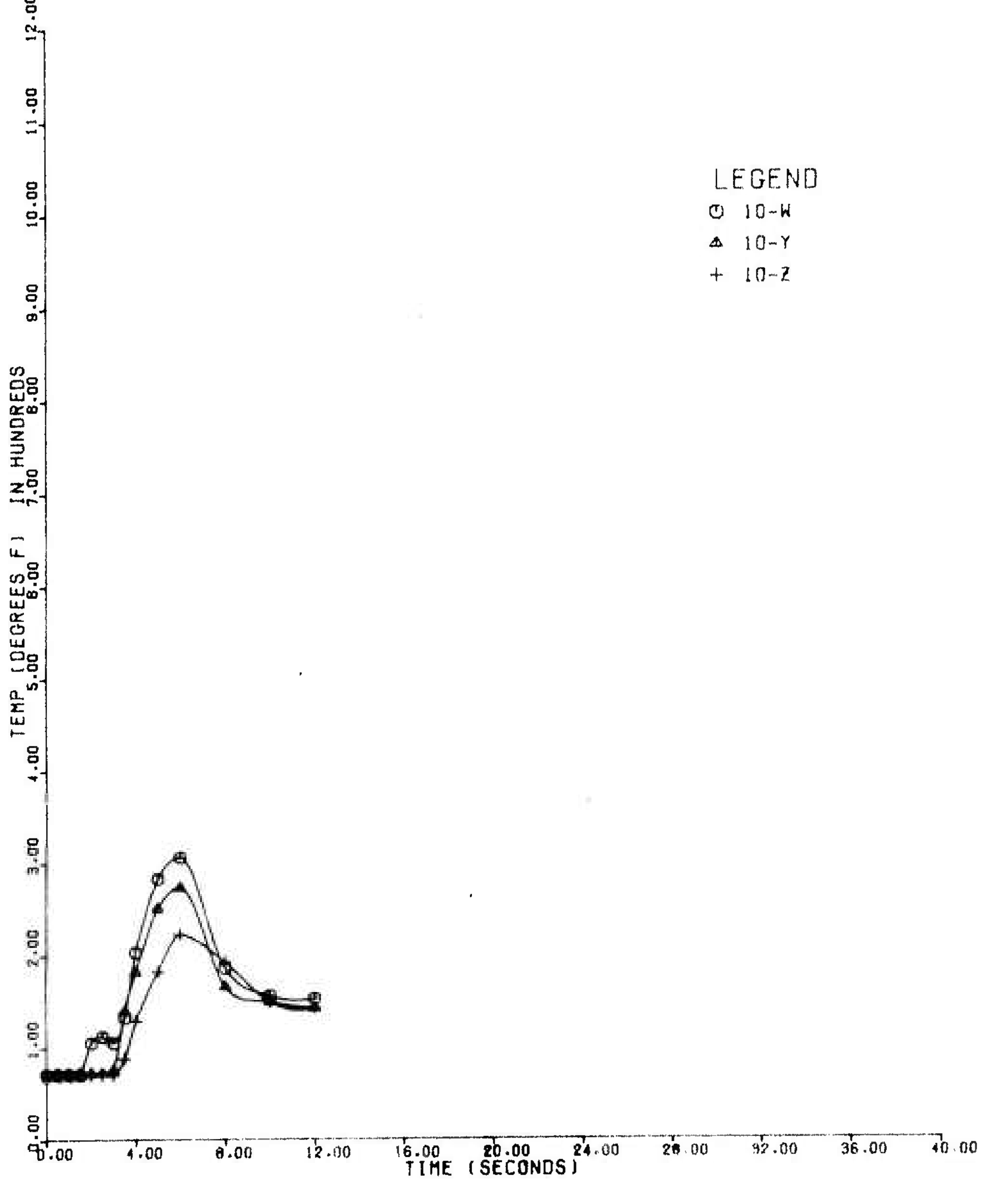


FIGURE B-13

CVA Magazine Test

No. 3

18 September 1973

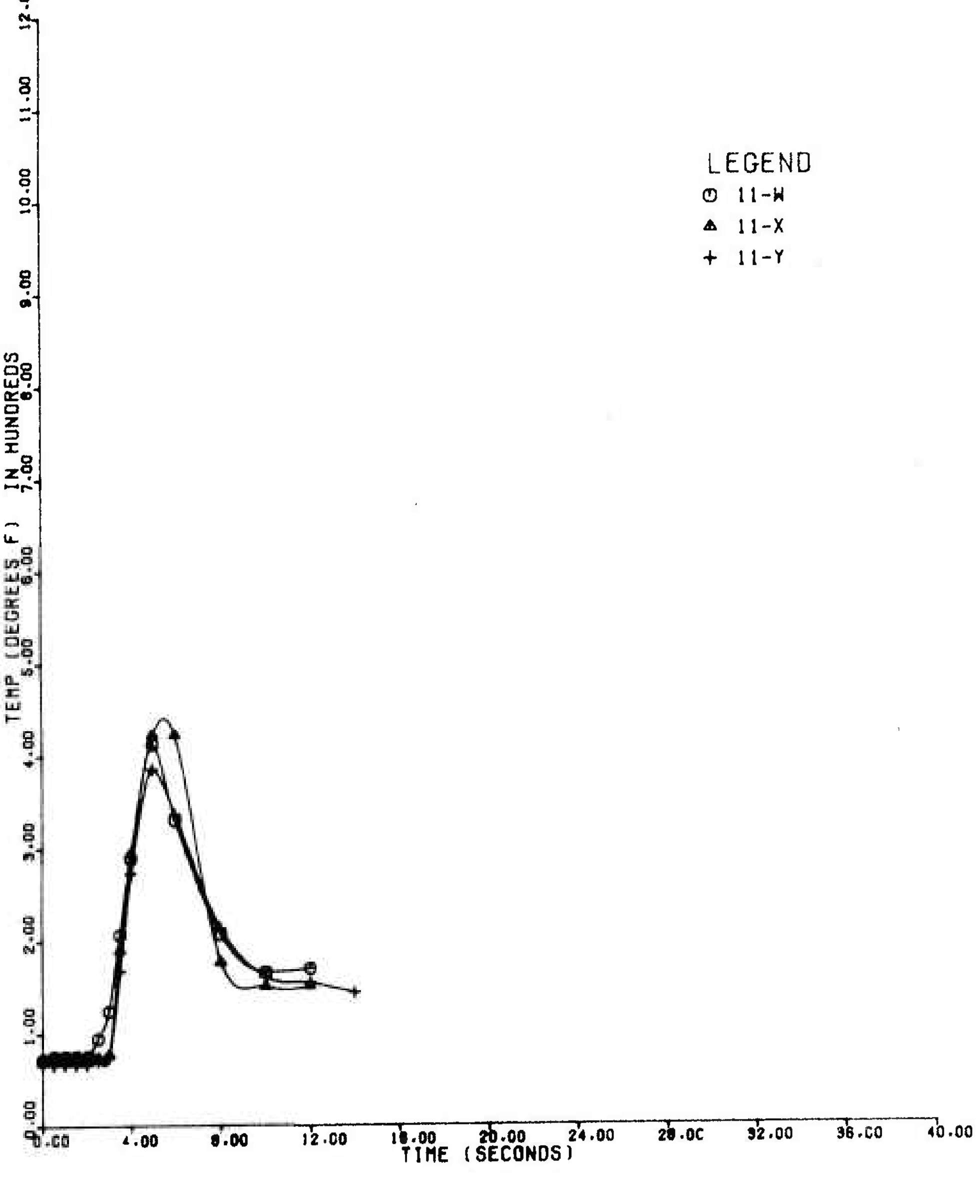


FIGURE B-14

CVA Magazine Test

No. 3

18 September 1973

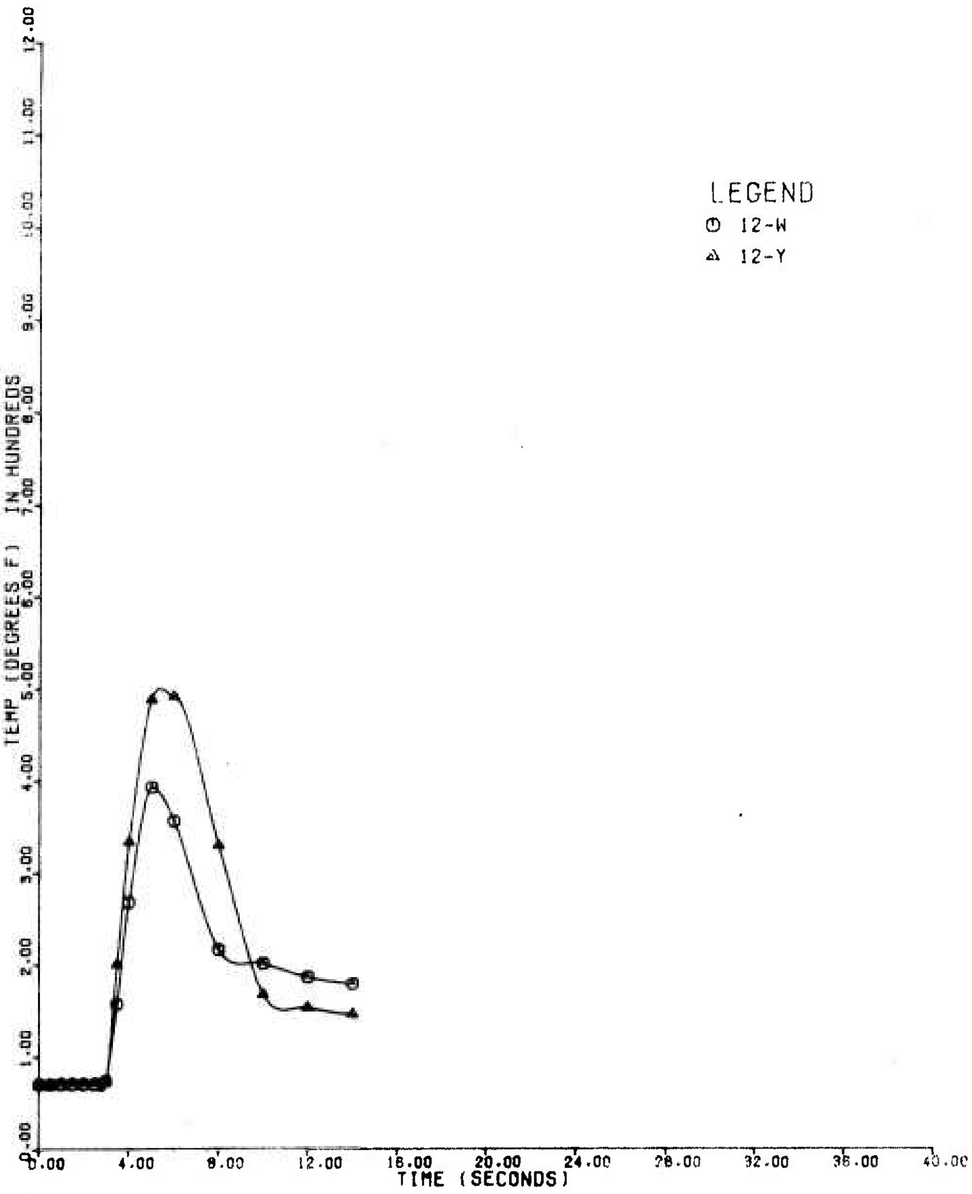


FIGURE B-15

CVA Magazine Test

No. 3

18 September 1973

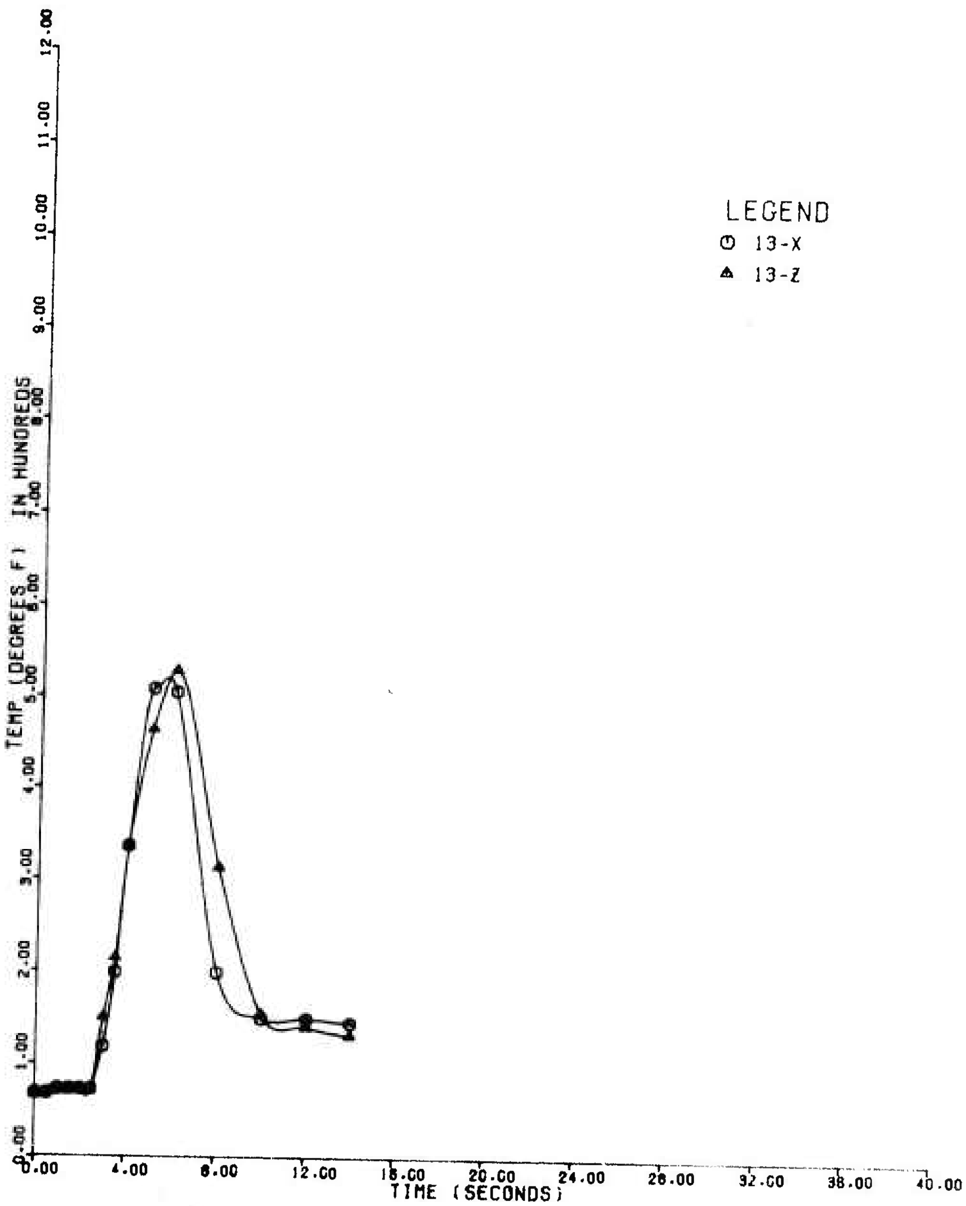


FIGURE B-16

CVA Magazine Test

No. 3

18 September 1973

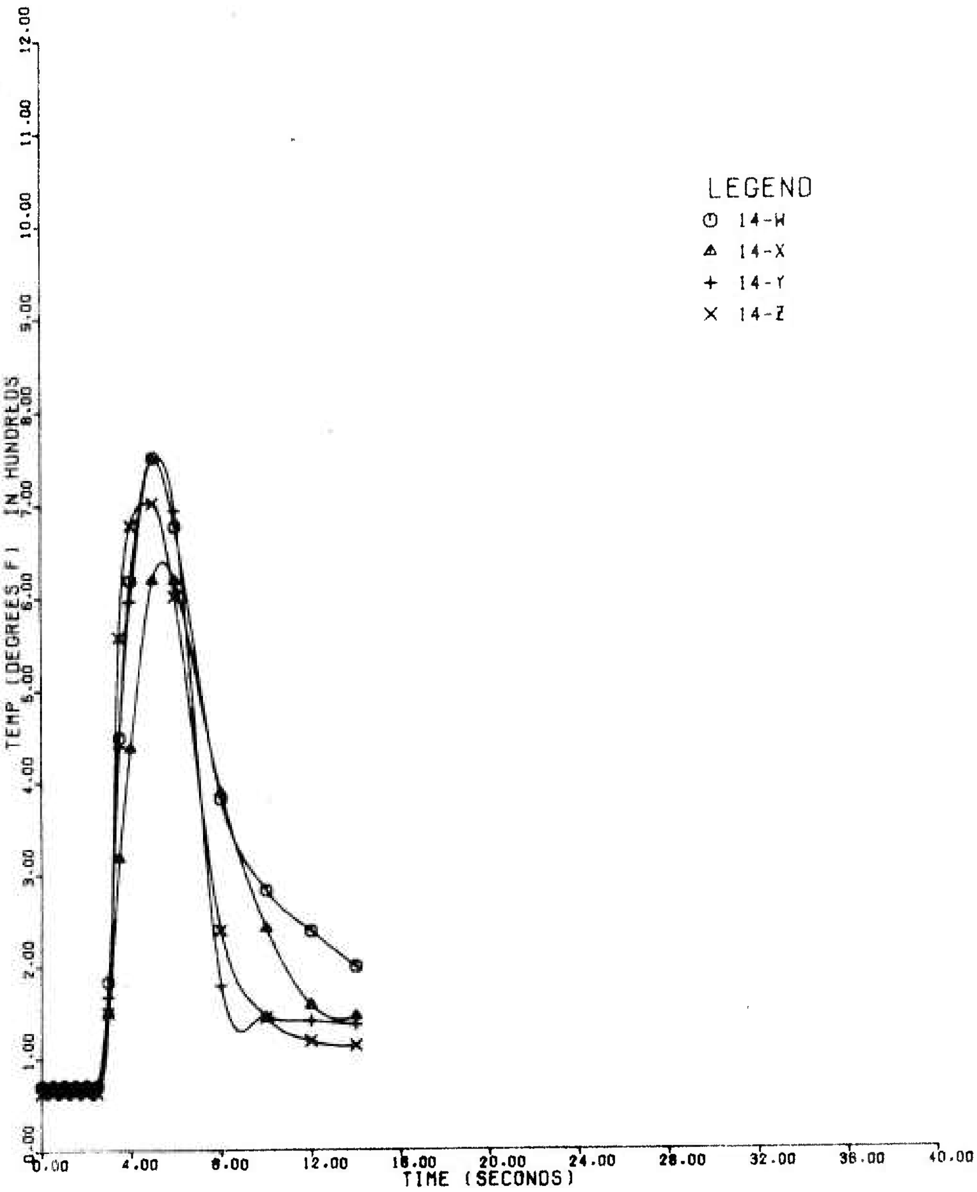


FIGURE B-17

CVA Magazine Test

No. 3 **18 September 1973**

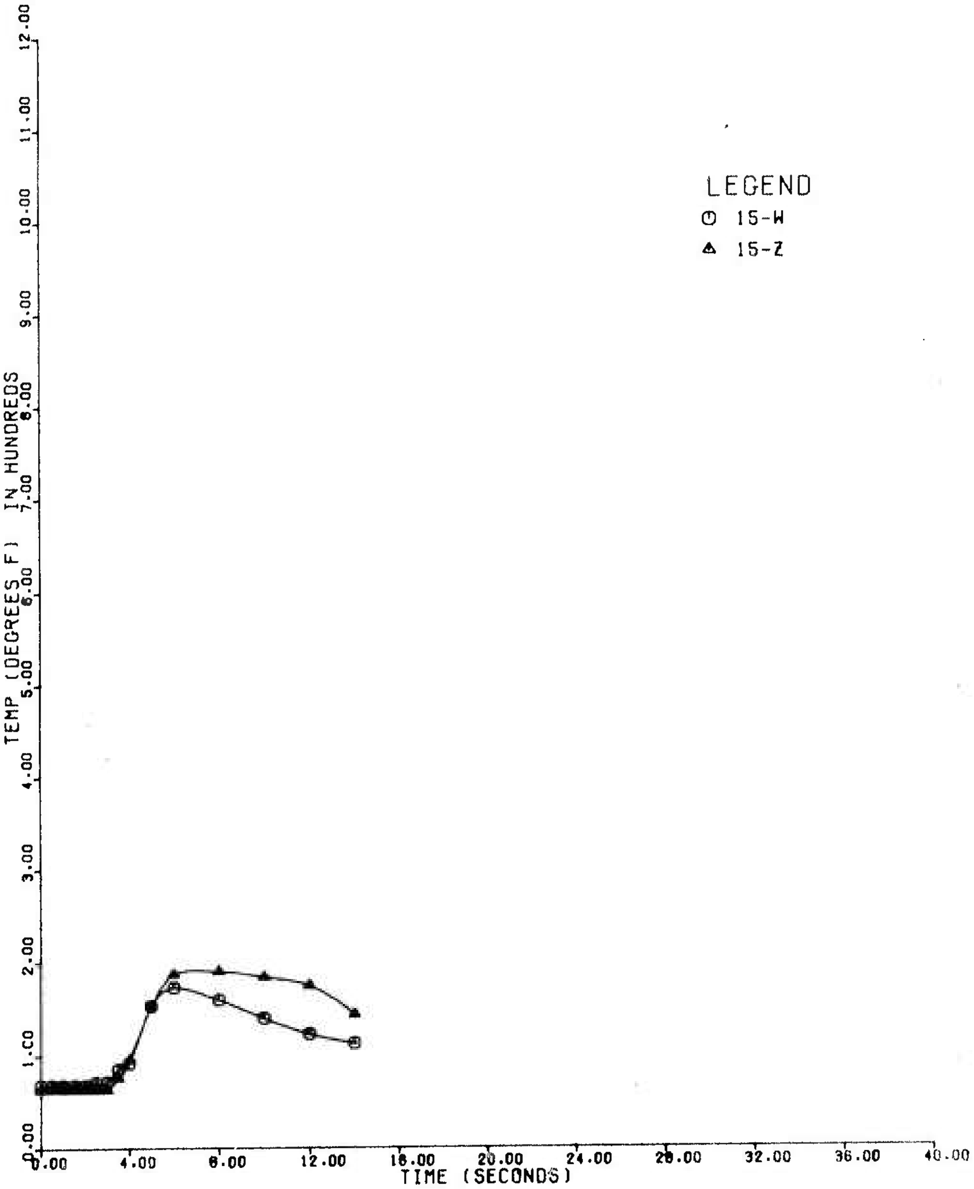


FIGURE B-18

CVA Magazine Test

No. 3

18 September 1973

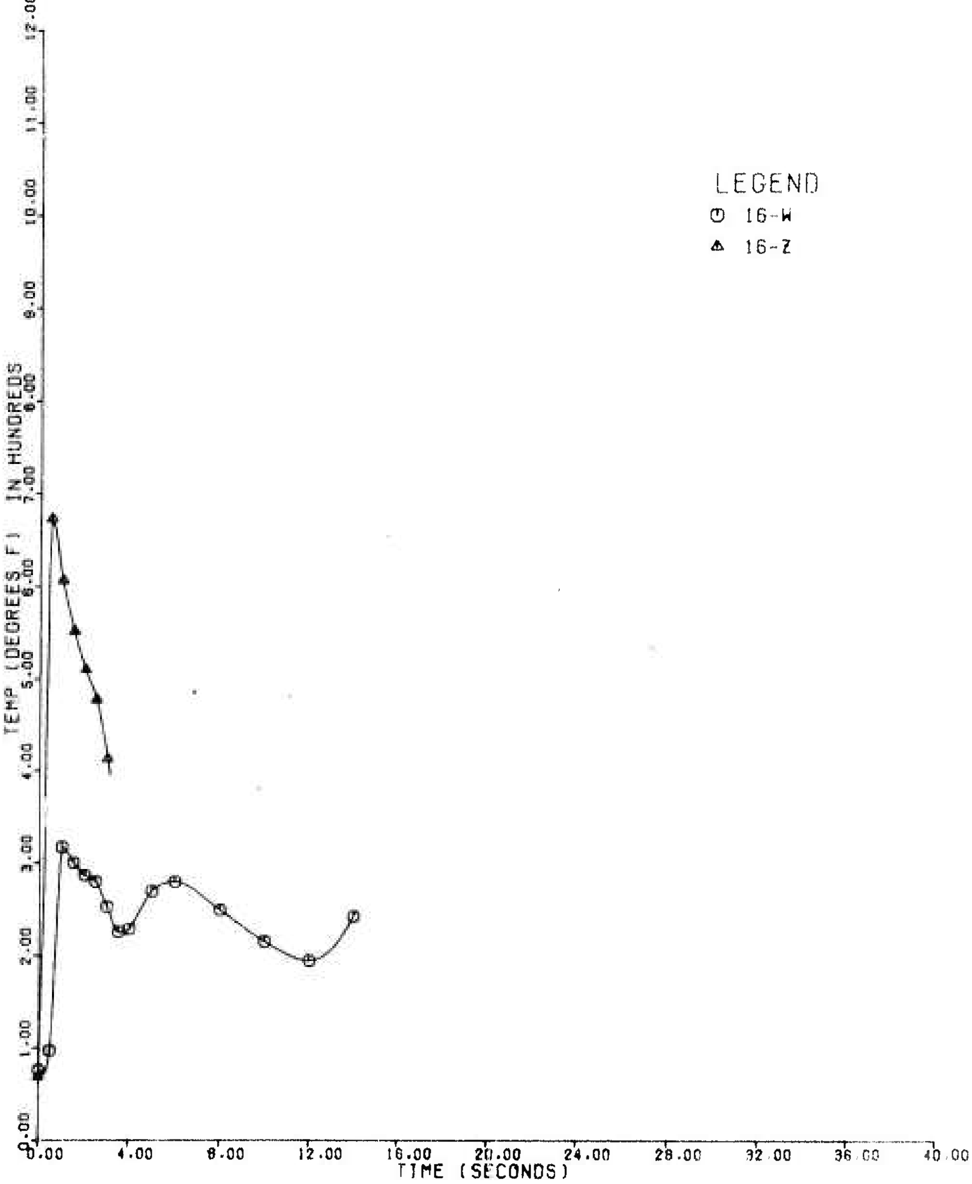


FIGURE B-19

CVA Magazine Test

No. 3 18 September 1973

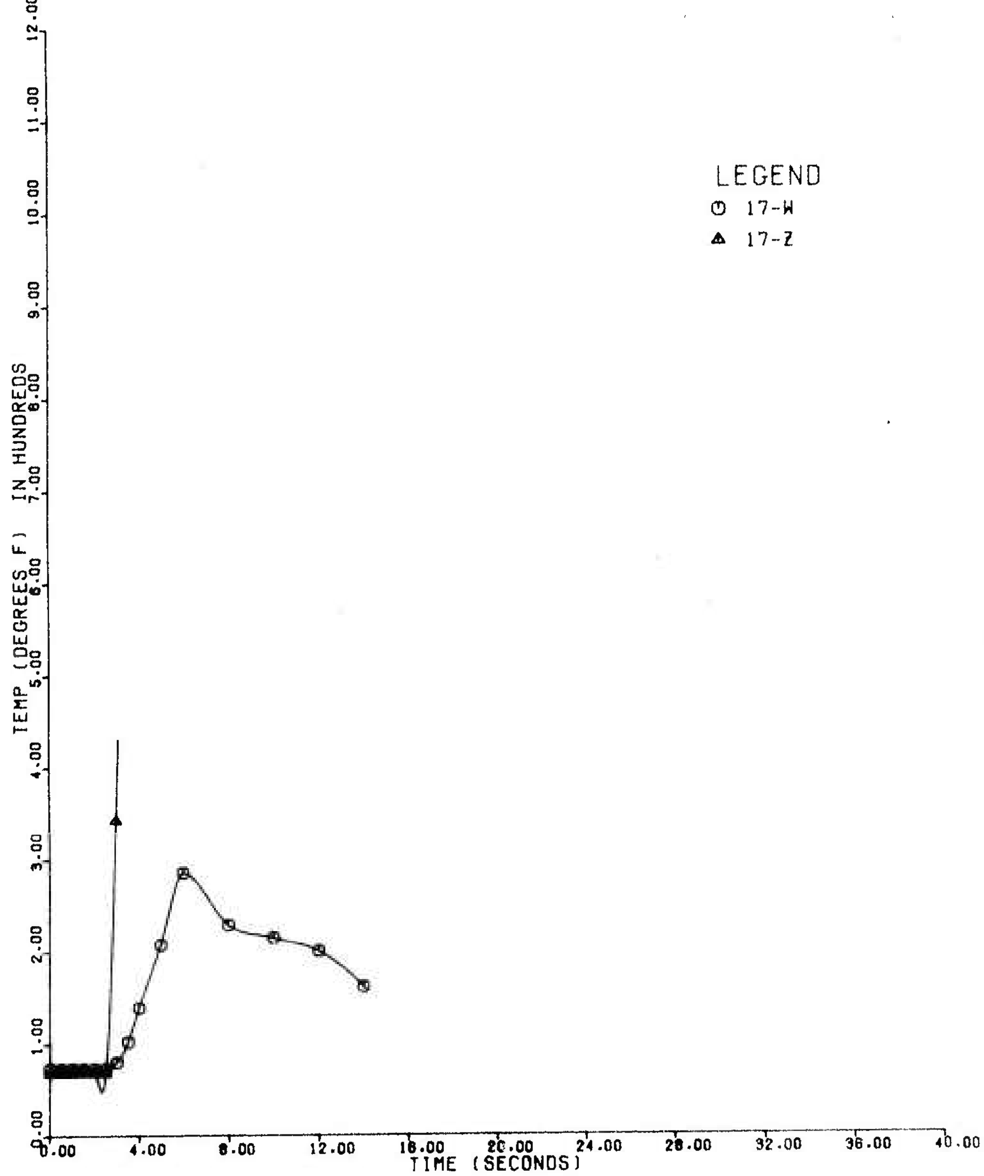


FIGURE B-20

CVA Magazine Test

No. 3 **18 September 1973**

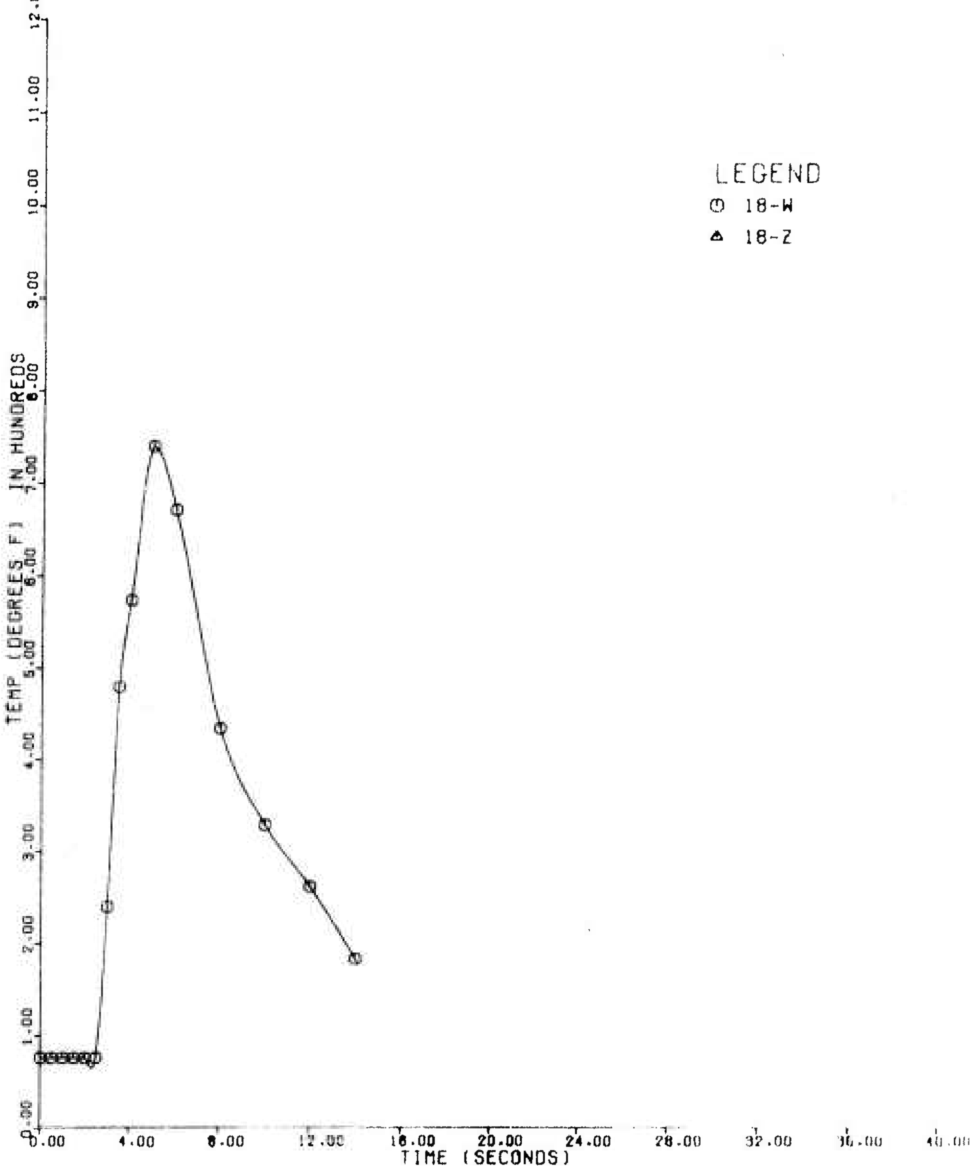


FIGURE B-21

CVA Magazine Test

No. 3 **18 September 1973**

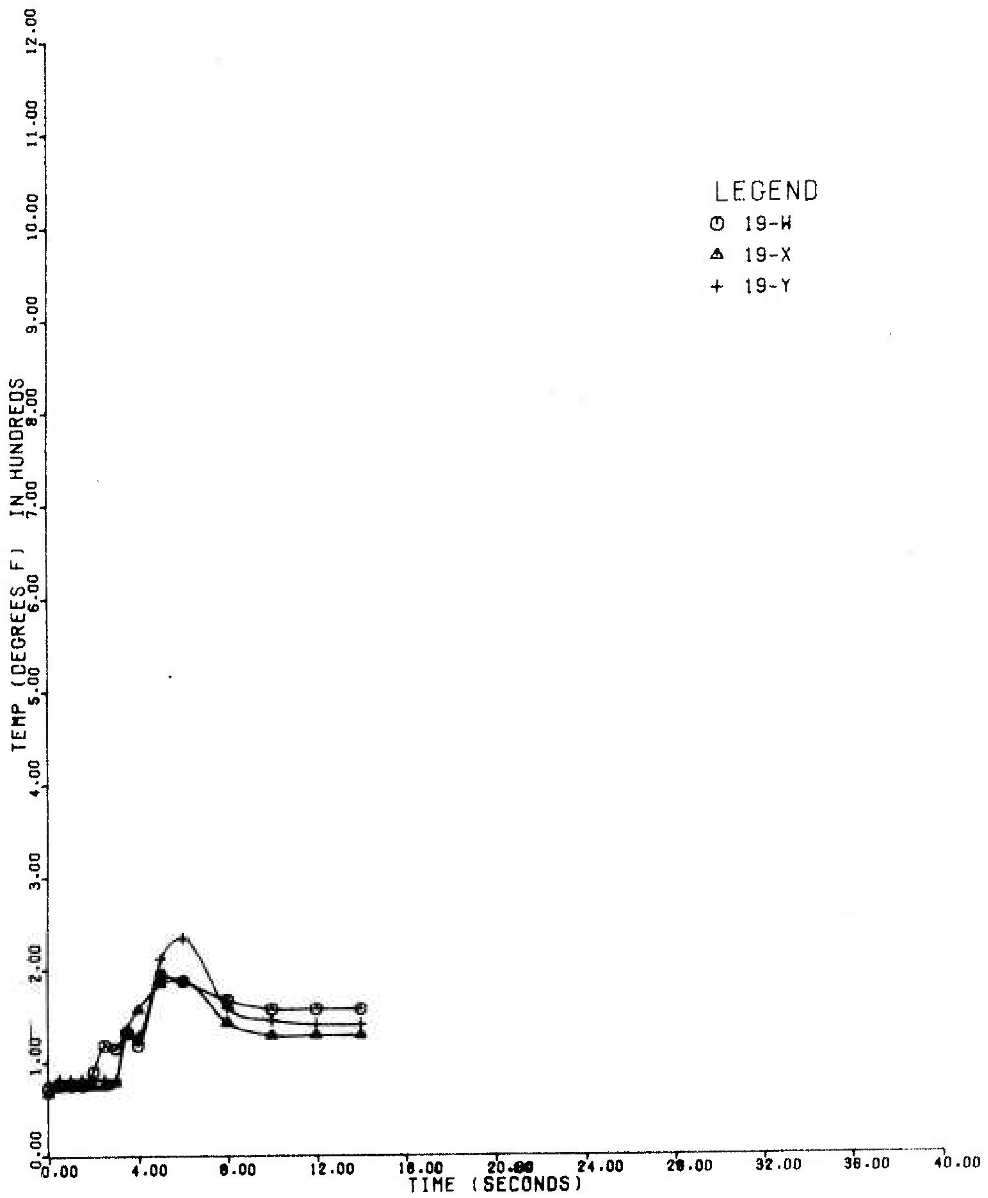


FIGURE B-22

CVA Magazine Test

No. 3 **18 September 1973**

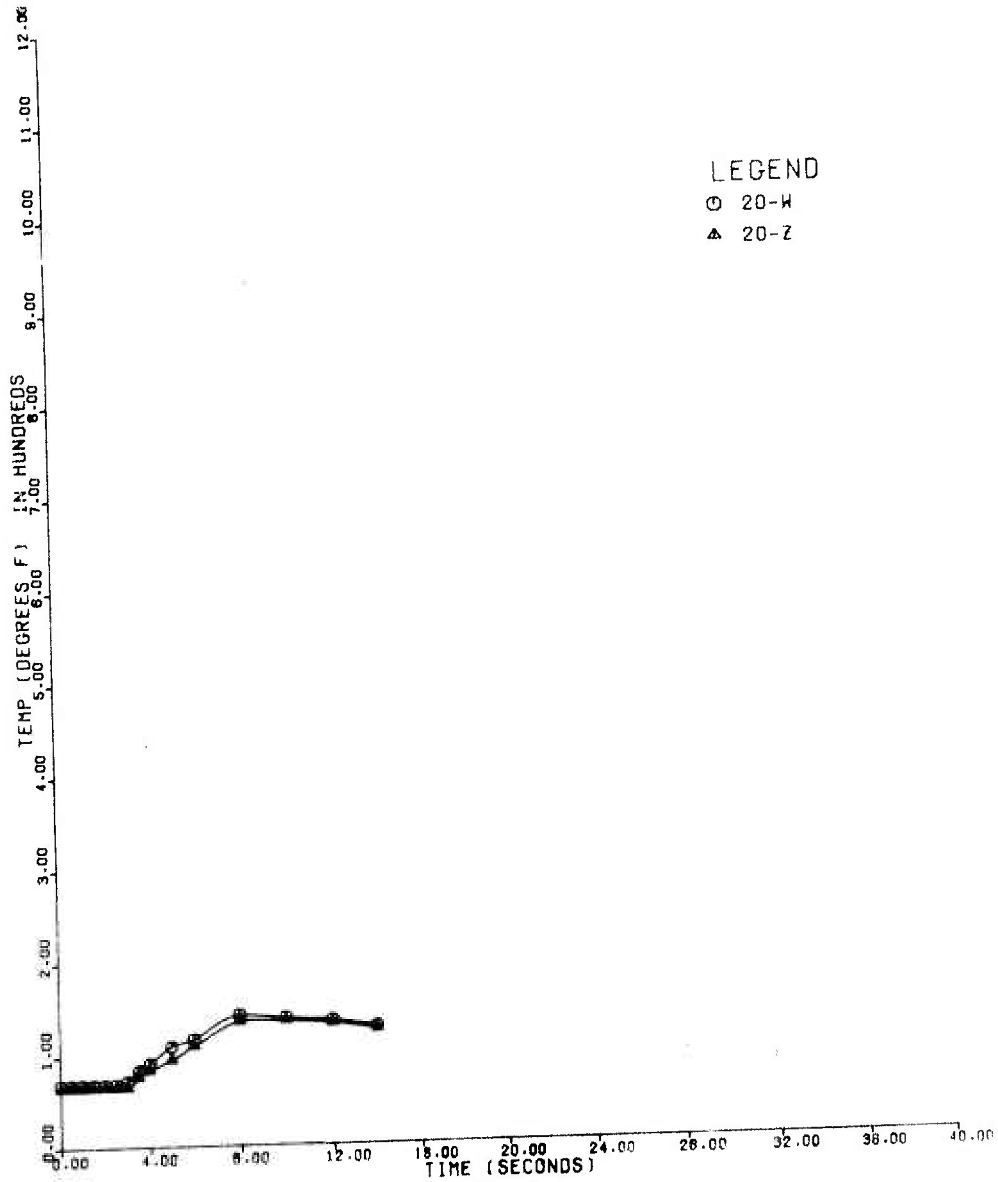


FIGURE B-23

CVA Magazine Test

No. 3

18 September 1973

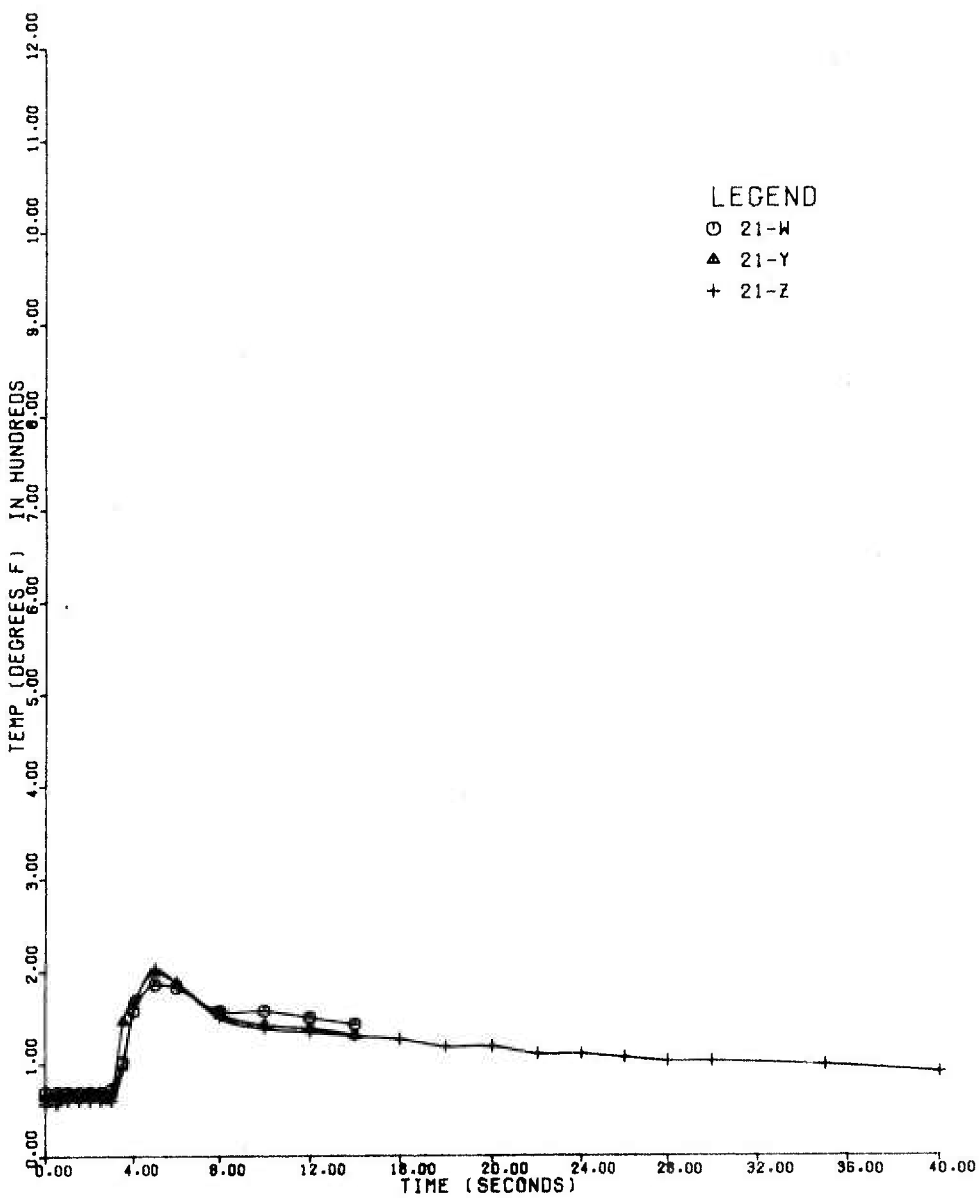


FIGURE B-24

CVA Magazine Test

No. 3

18 September 1973

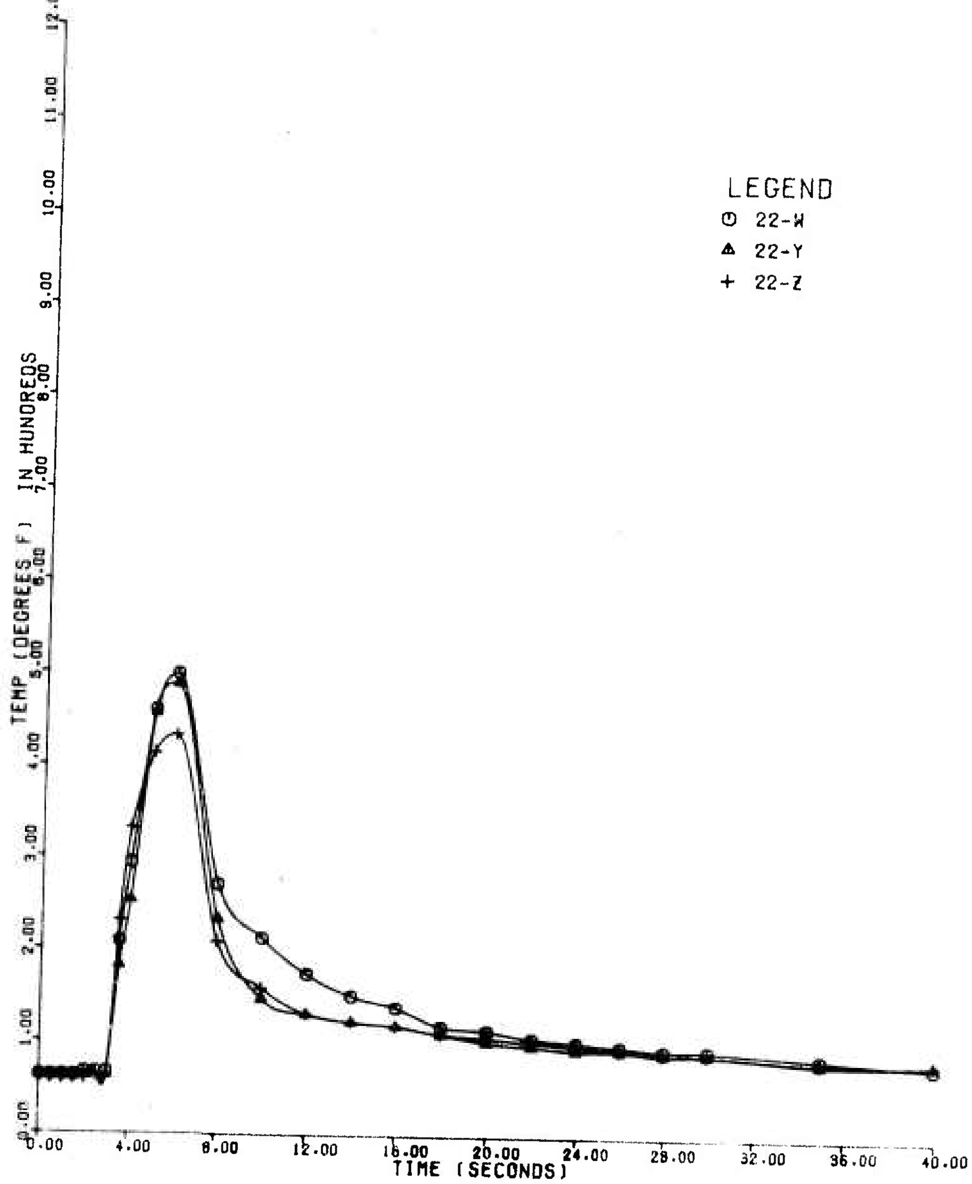


FIGURE B-25

No. 3

CVA Magazine Test

18 September 1973

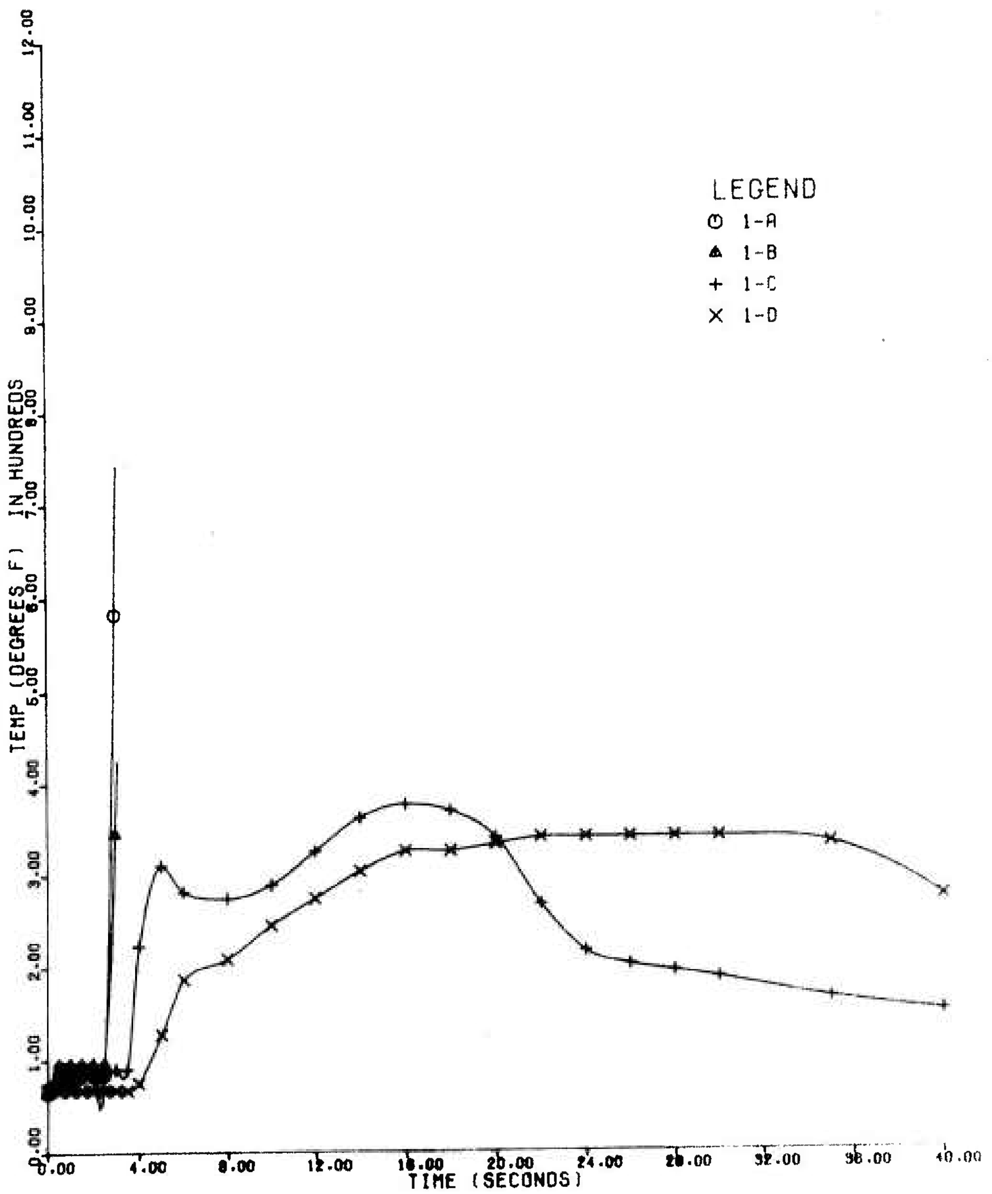


FIGURE B-26

CVA Magazine Test

No. 3

21 September 1973

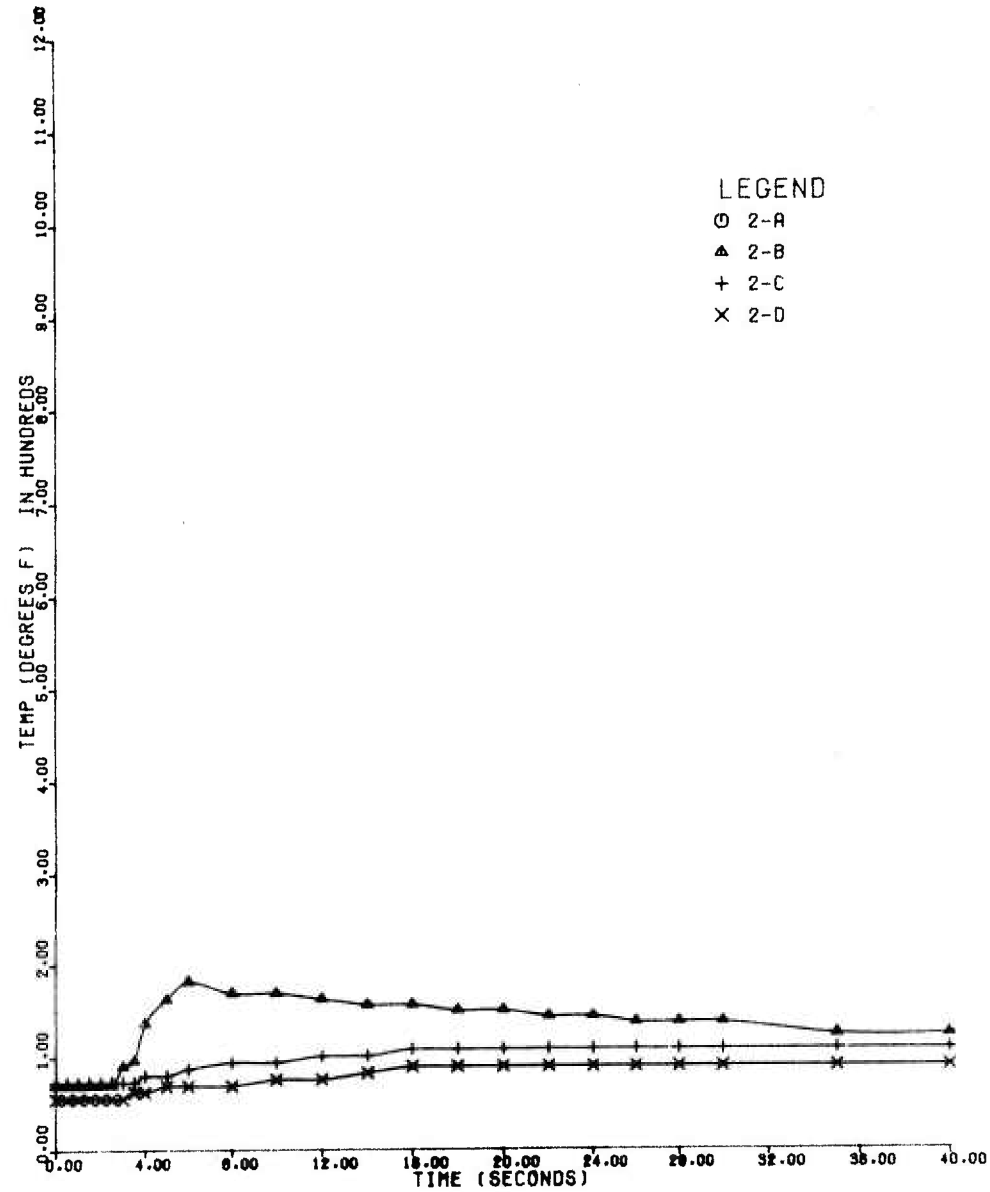


FIGURE B-27

CVA Magazine Test

No. 3 21 September 1973

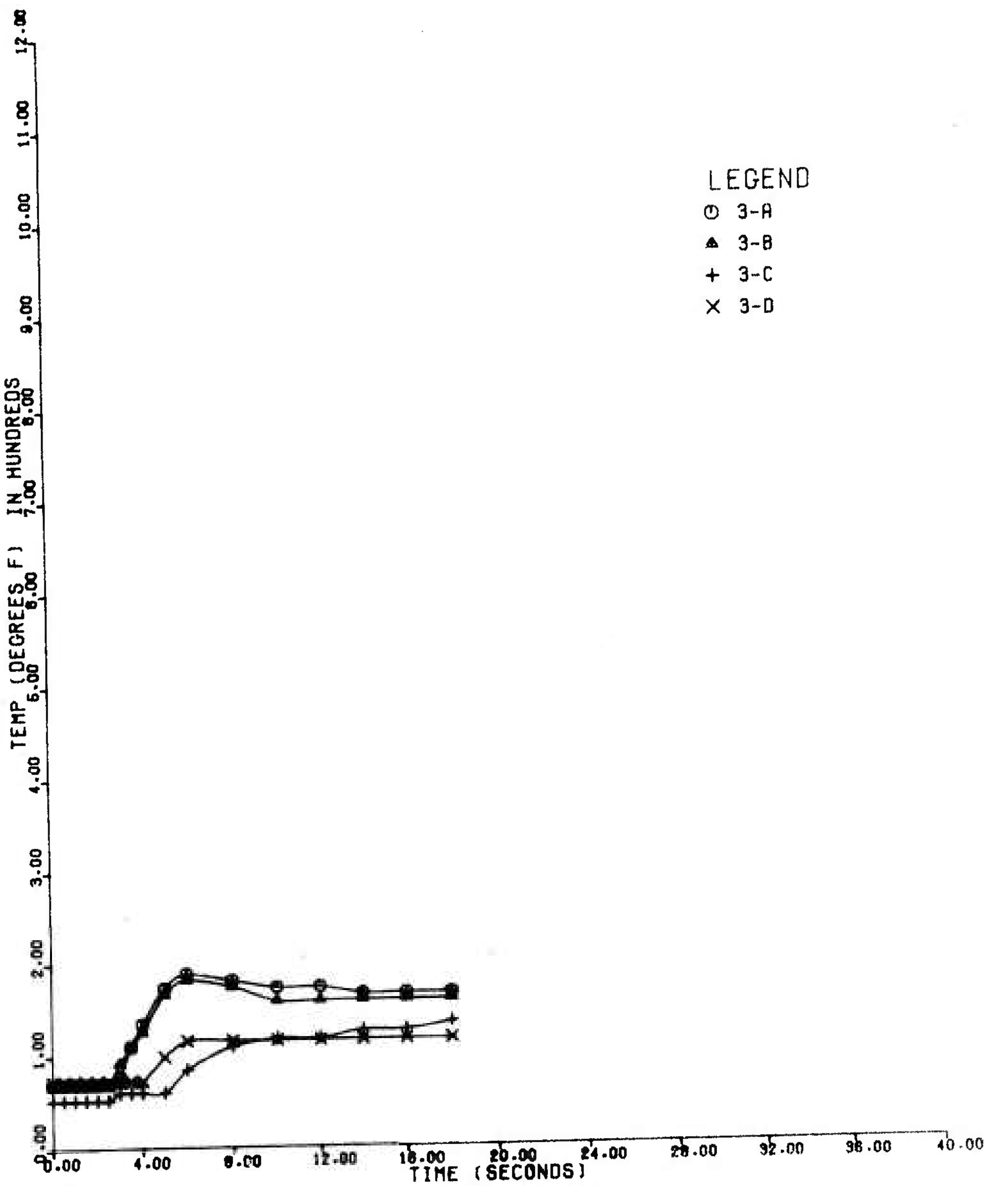


FIGURE B-28

CVA Magazine Test

No. 3

21 September 1973

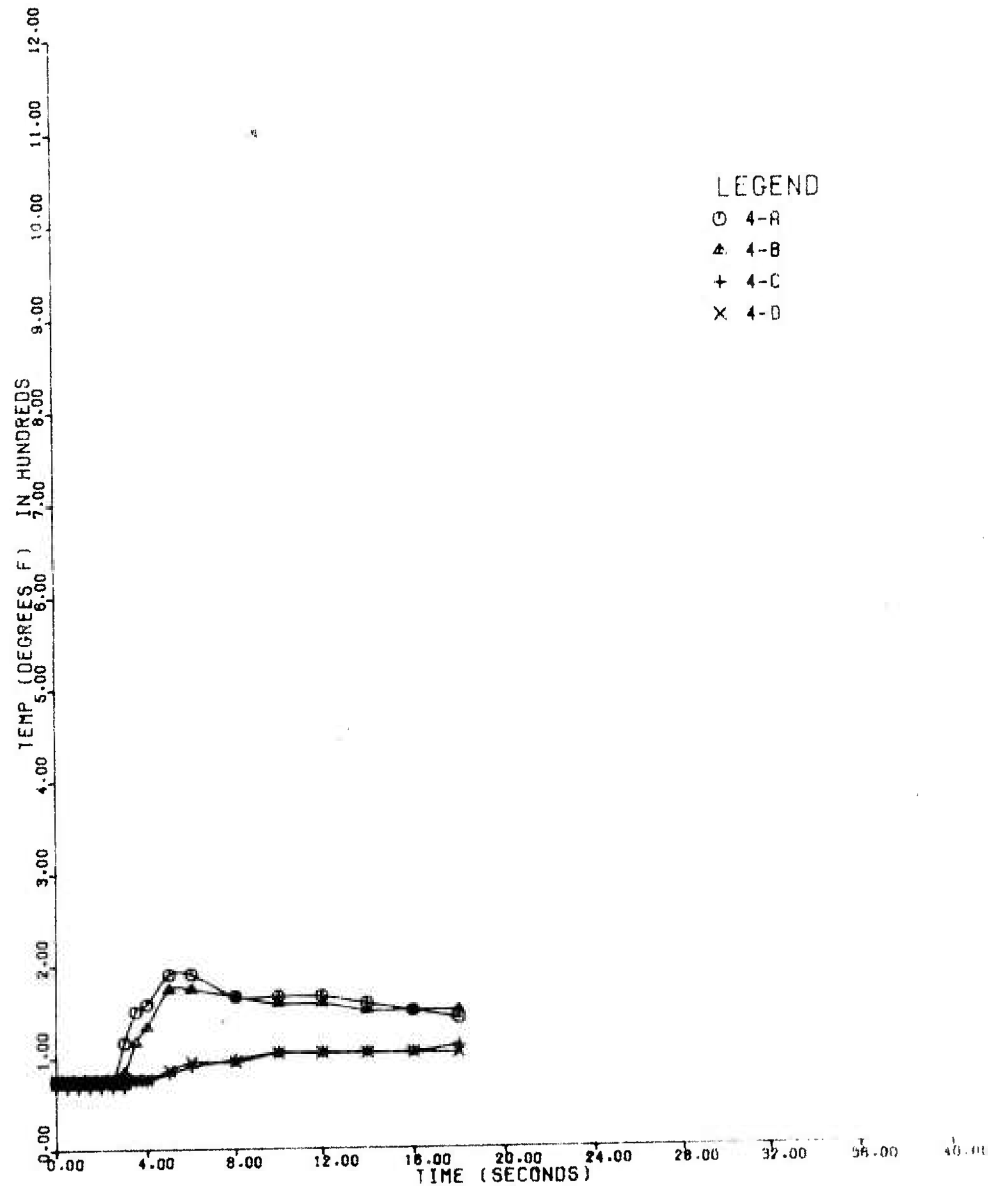


FIGURE B-29

CVA Magazine Test

No. 3 **21 September 1973**

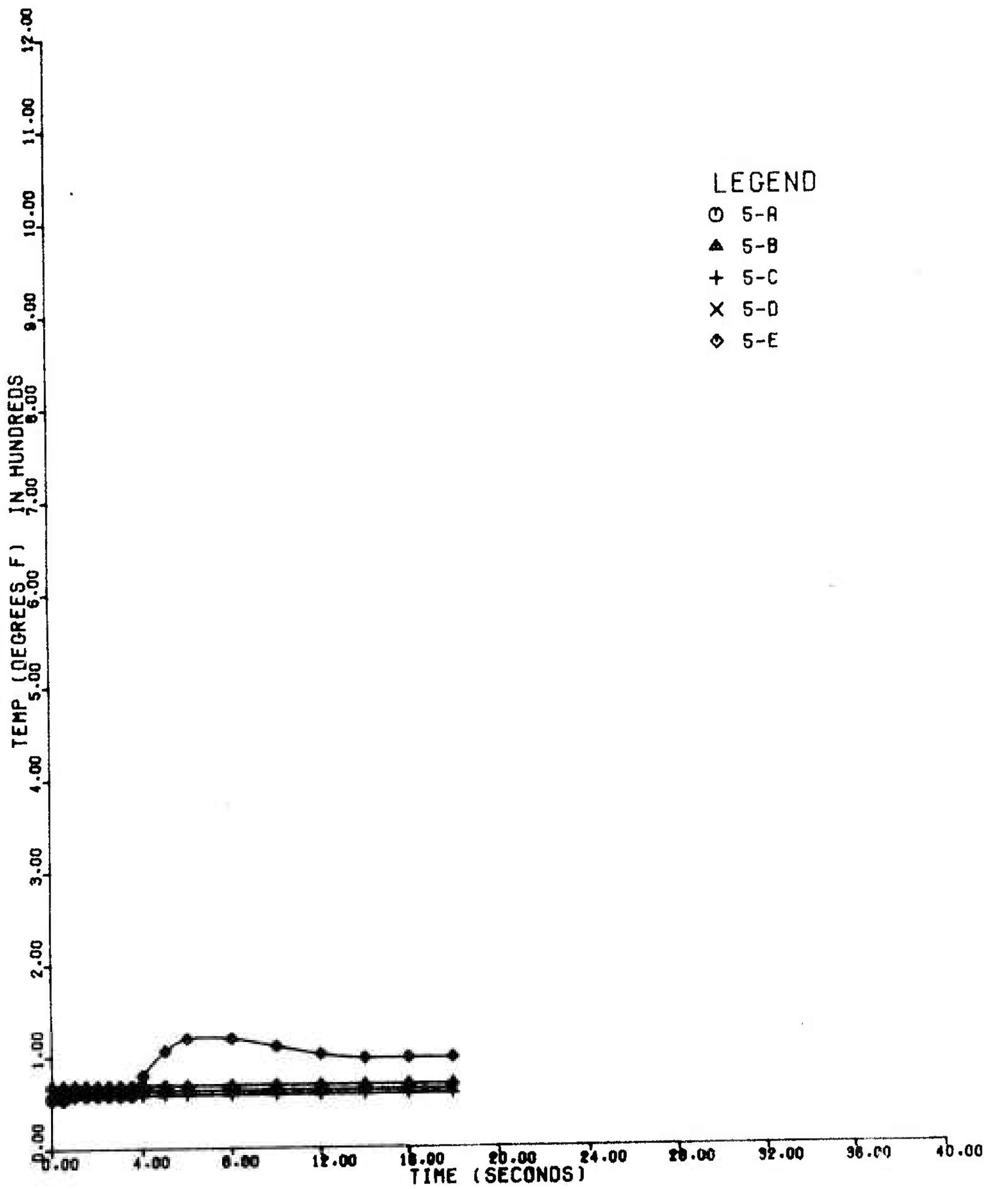


FIGURE B-30

CVA Magazine Test

No. 3

21 September 1973

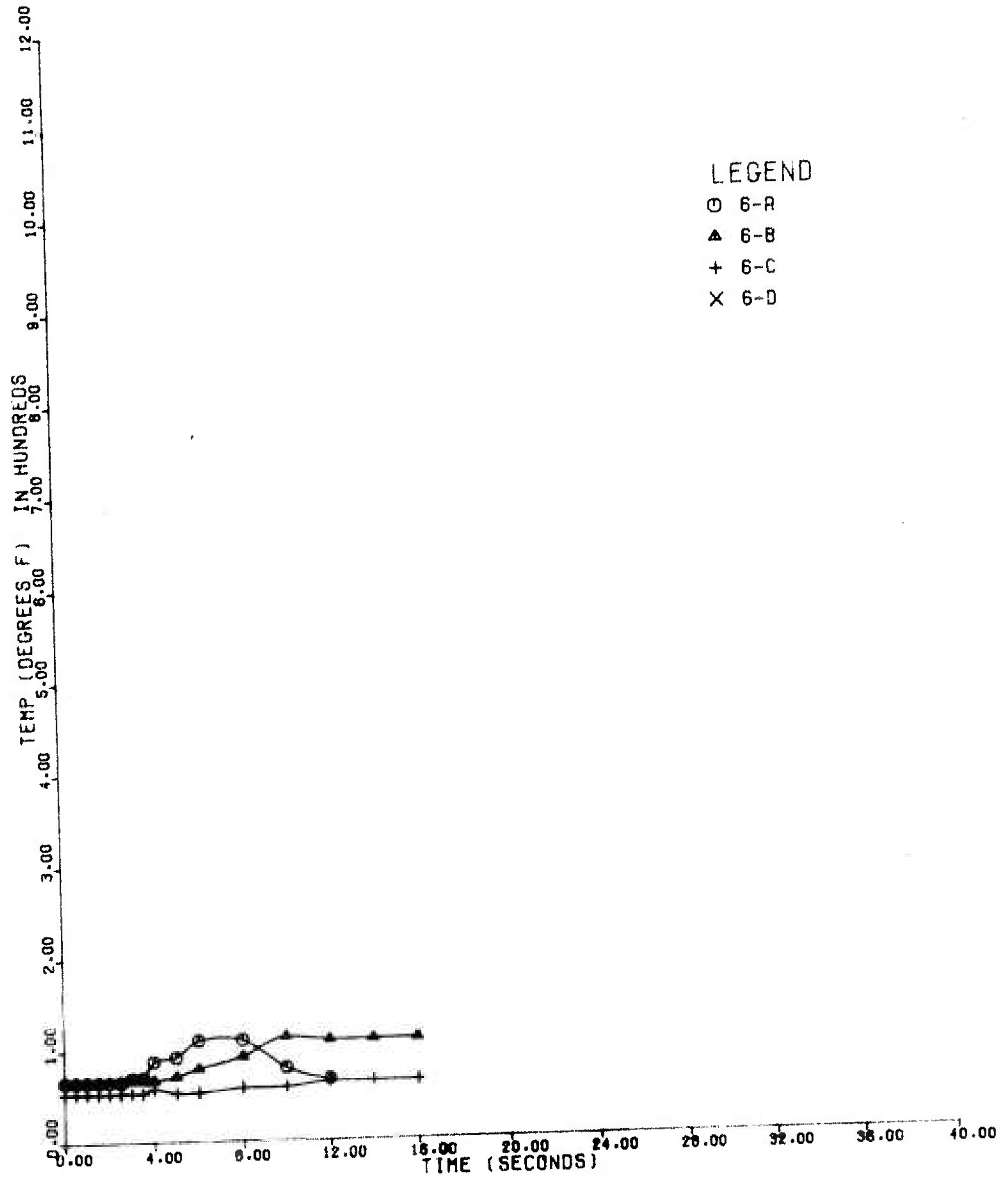


FIGURE B-31

CVA Magazine Test

No. 3

21 September 1973

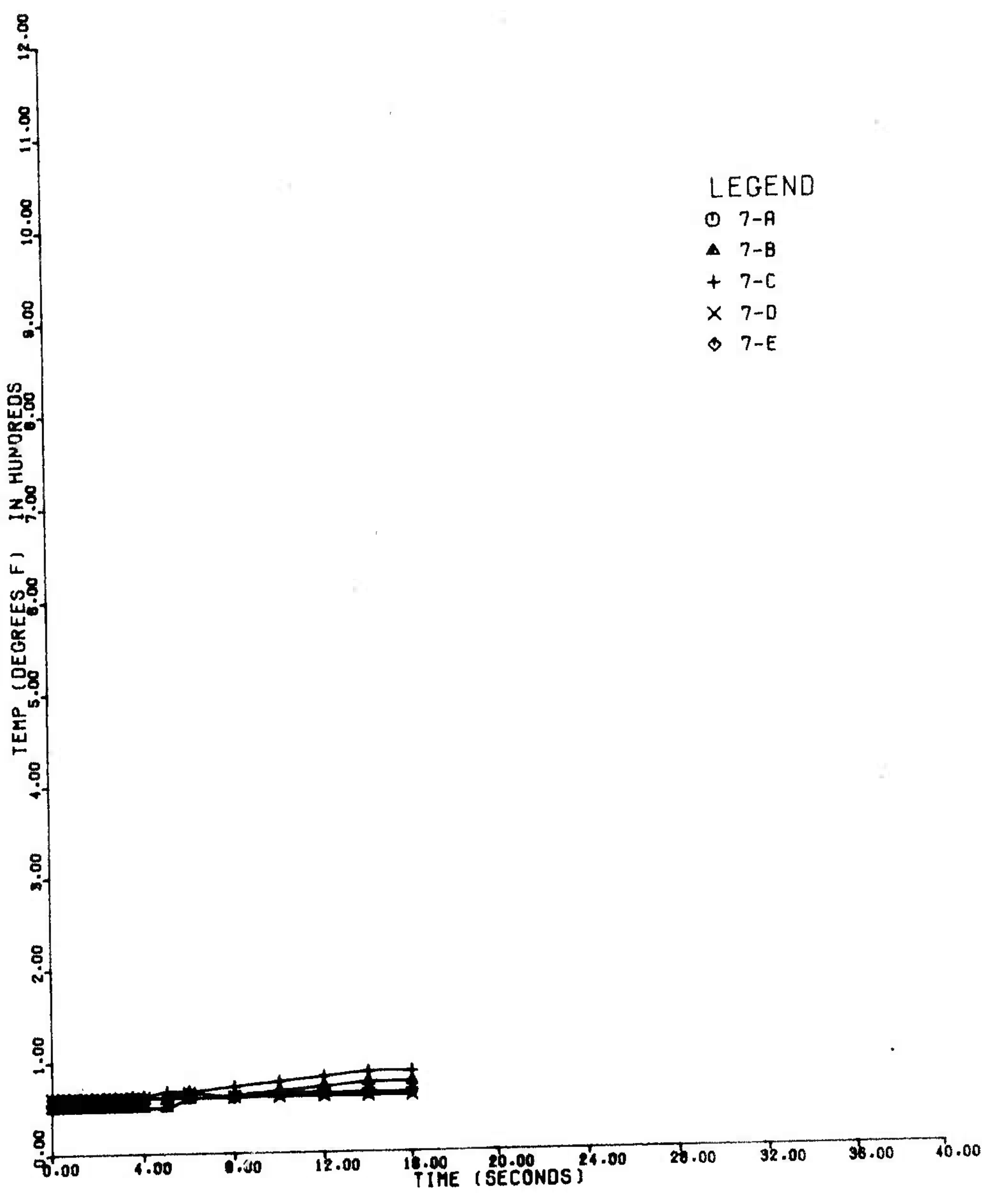


FIGURE B-32

CVA Magazine Test

No. 3

21 September 1973

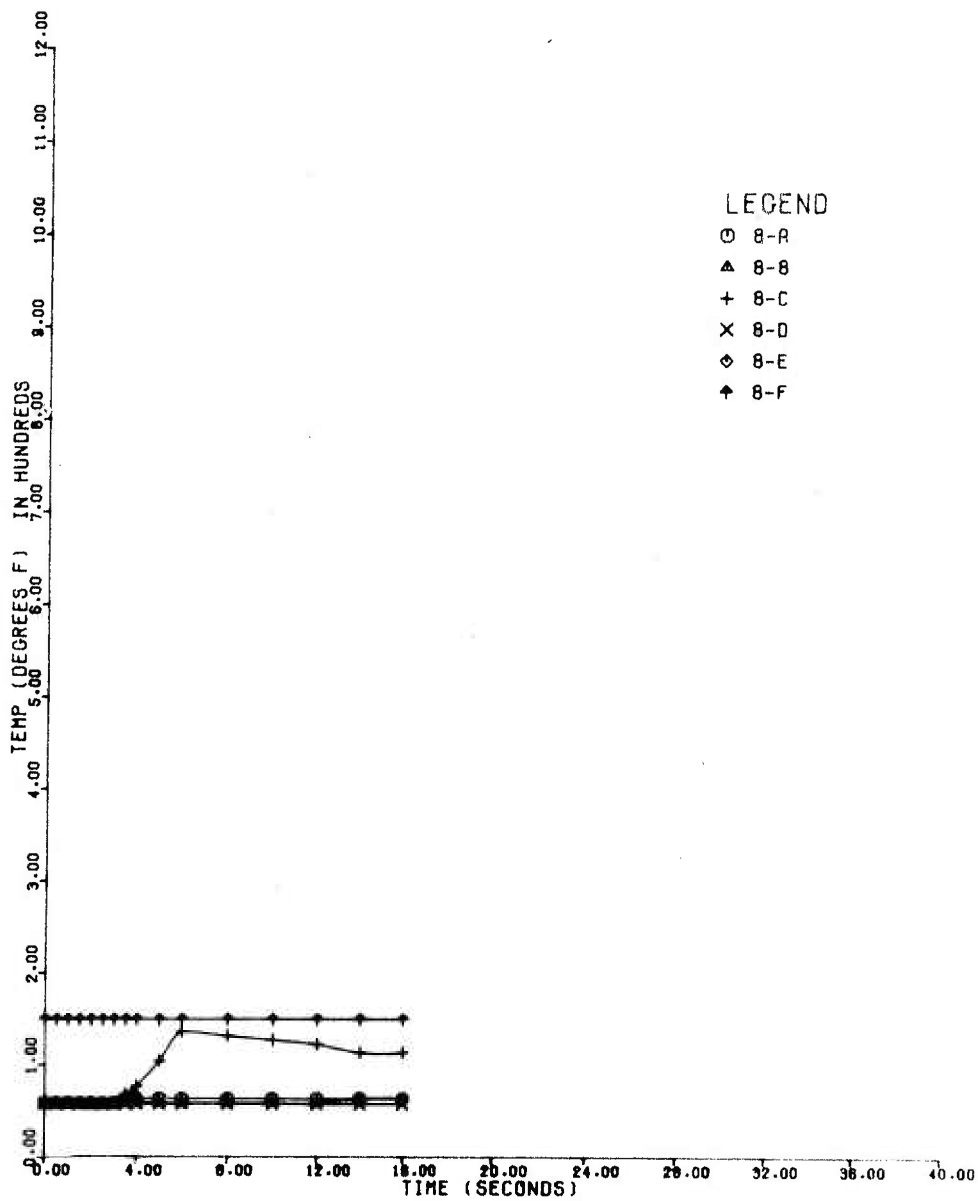


FIGURE B-33

CVA Magazine Test

No. 3 **21 September 1973**

APPENDIX C

TEST DATA OBTAINED DURING TEST NO. 4

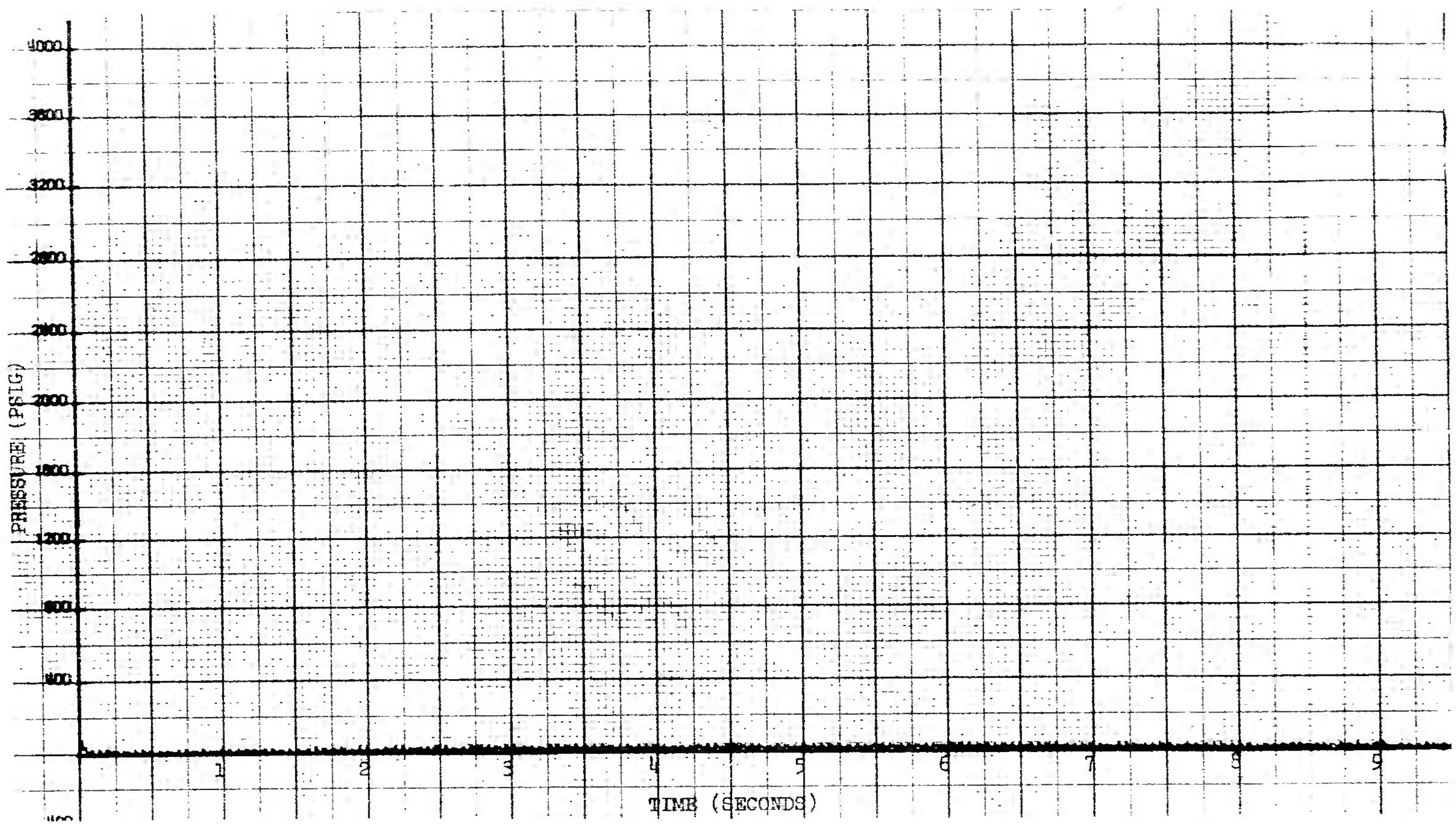


FIGURE C-1

SPARROW MK 38 MOD 0 Motor Pressure
Test No. 4

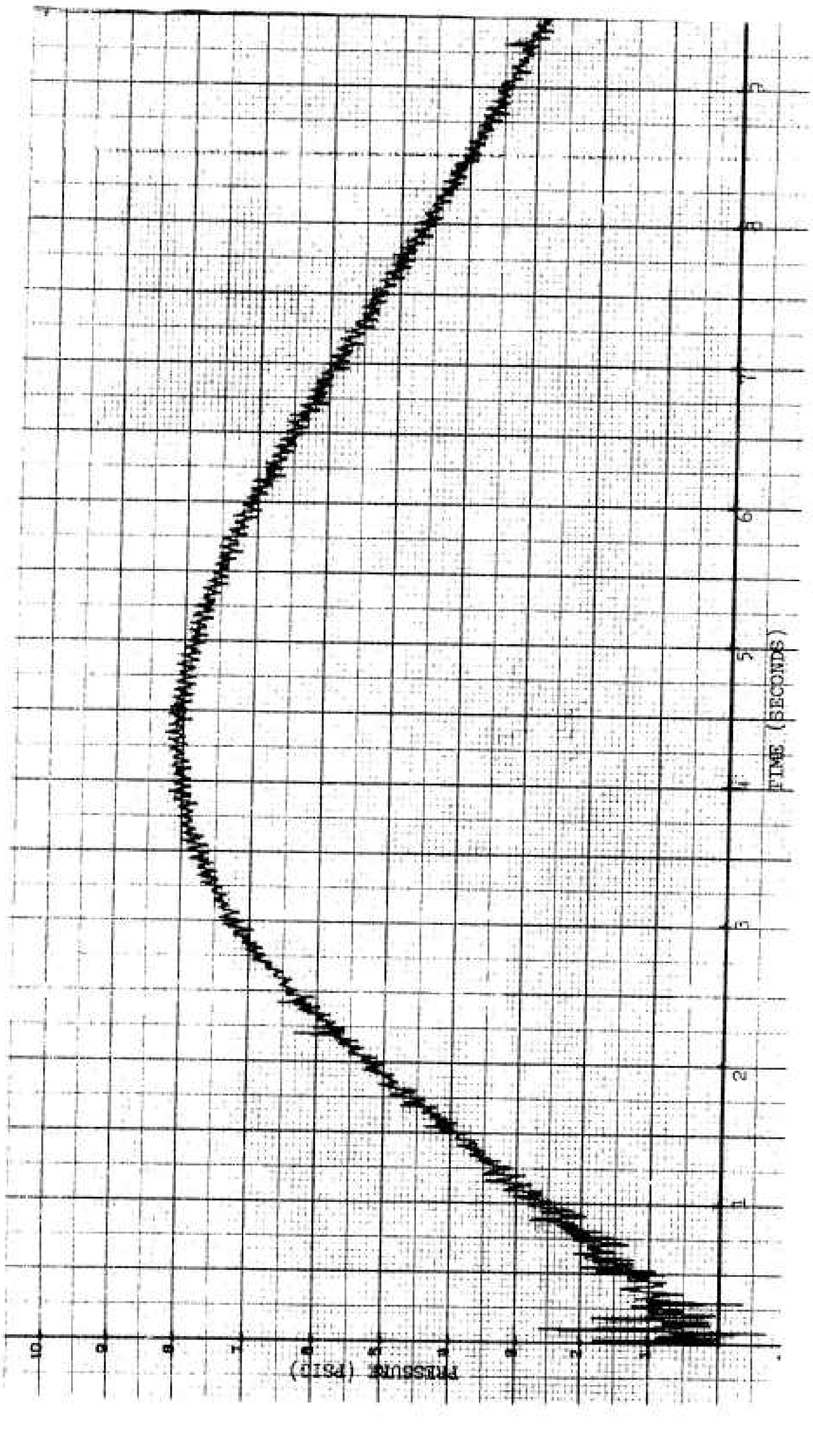


FIGURE C-2

Pressure Transducer No. 1
Test No. 4

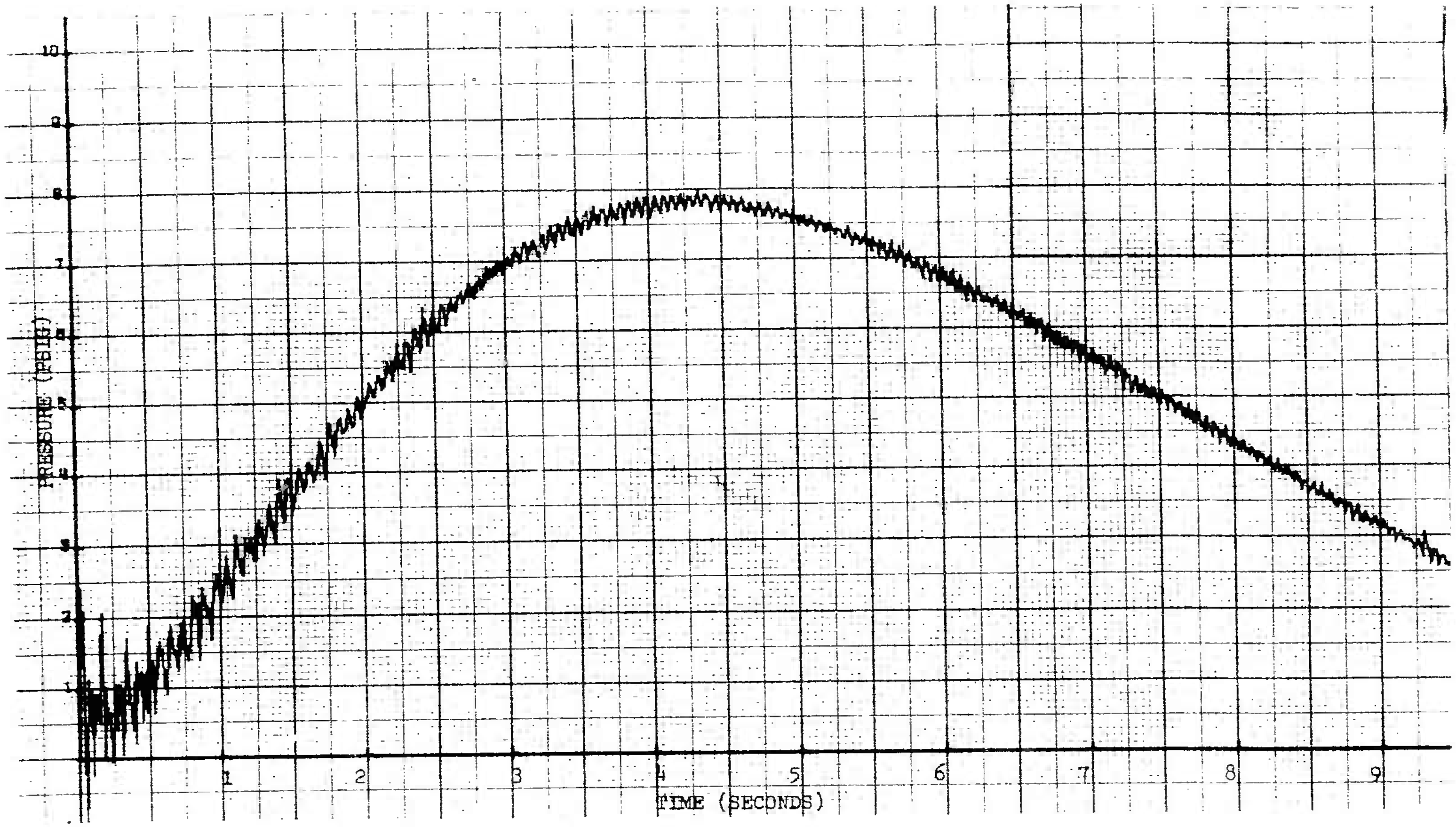


FIGURE C-3

Pressure Transducer No. 2
Test No. 4

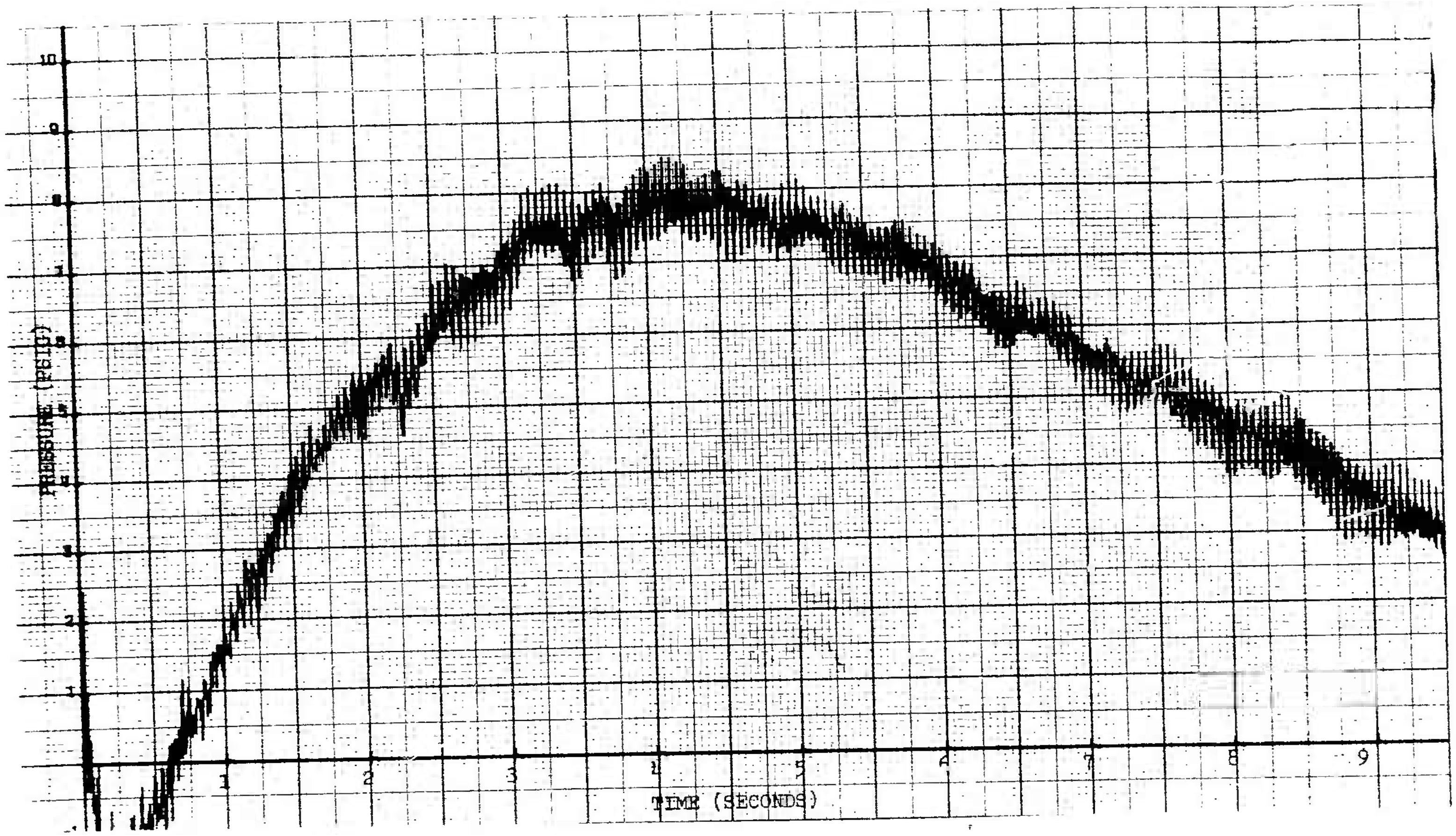


FIGURE C-4

Pressure Transducer No. 3
Test No. 4

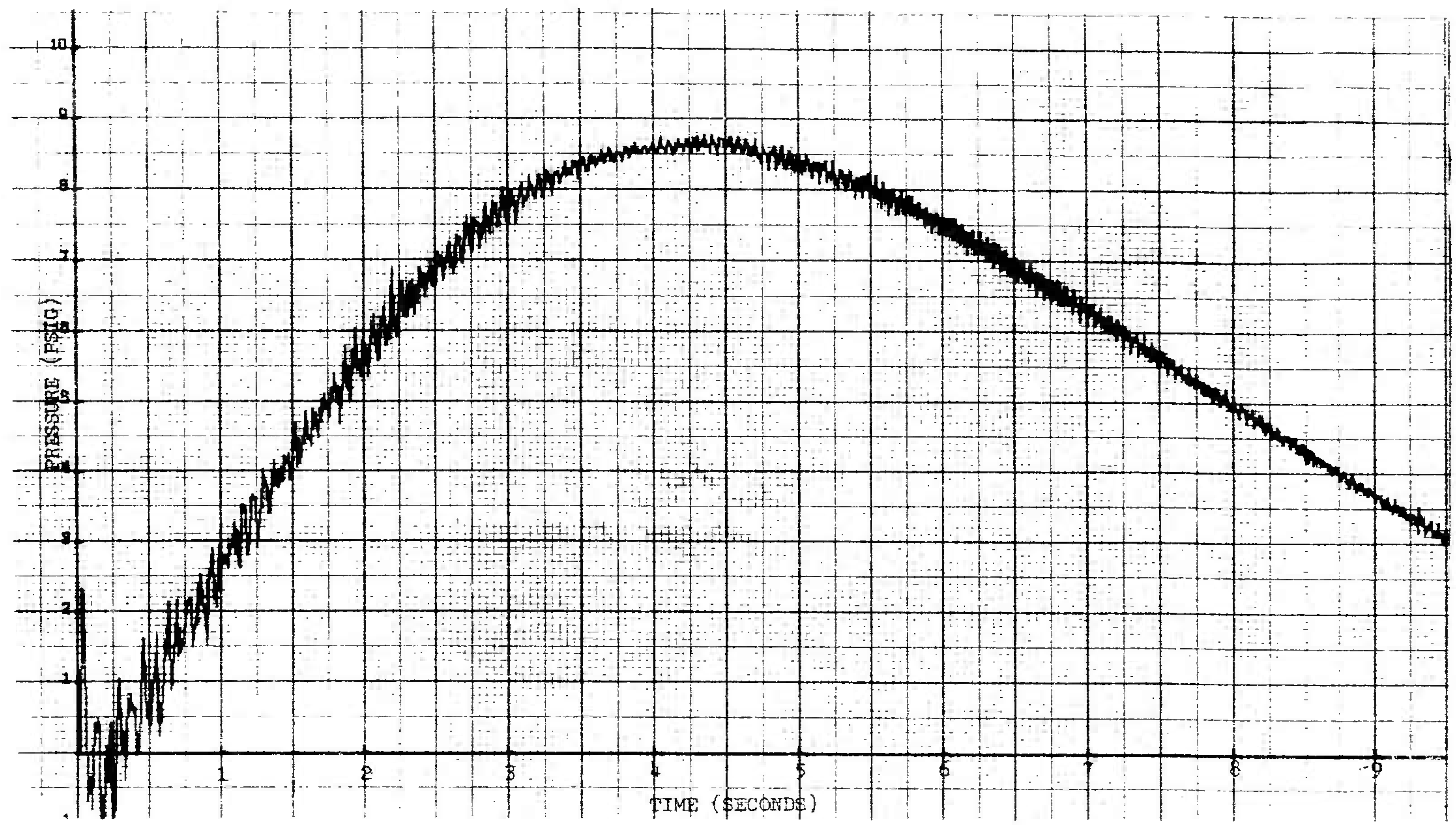


FIGURE C-5

Pressure Transducer No. 4
Test No. 4

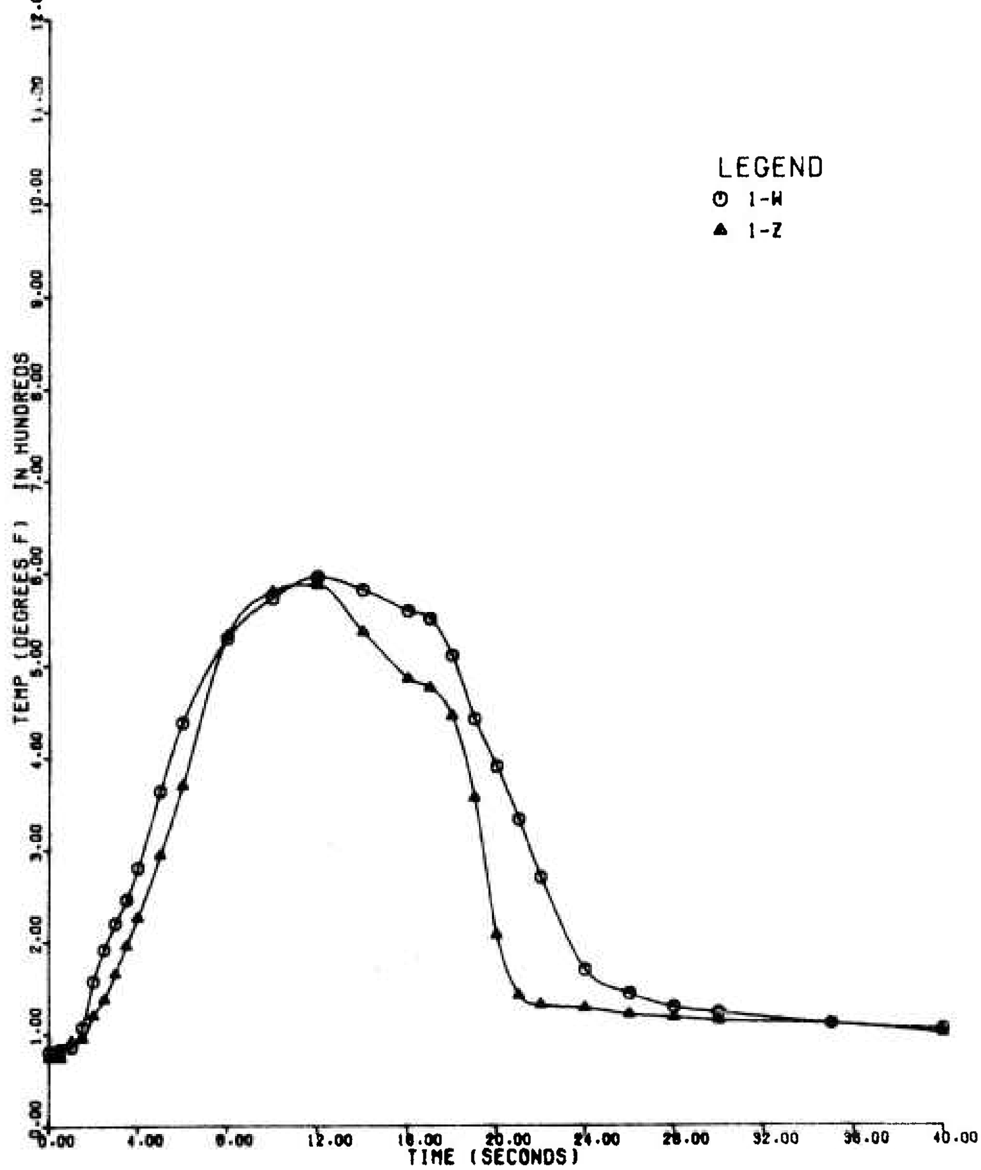


FIGURE C-6

CVA Magazine Test

No. 4 **27 September 1973**

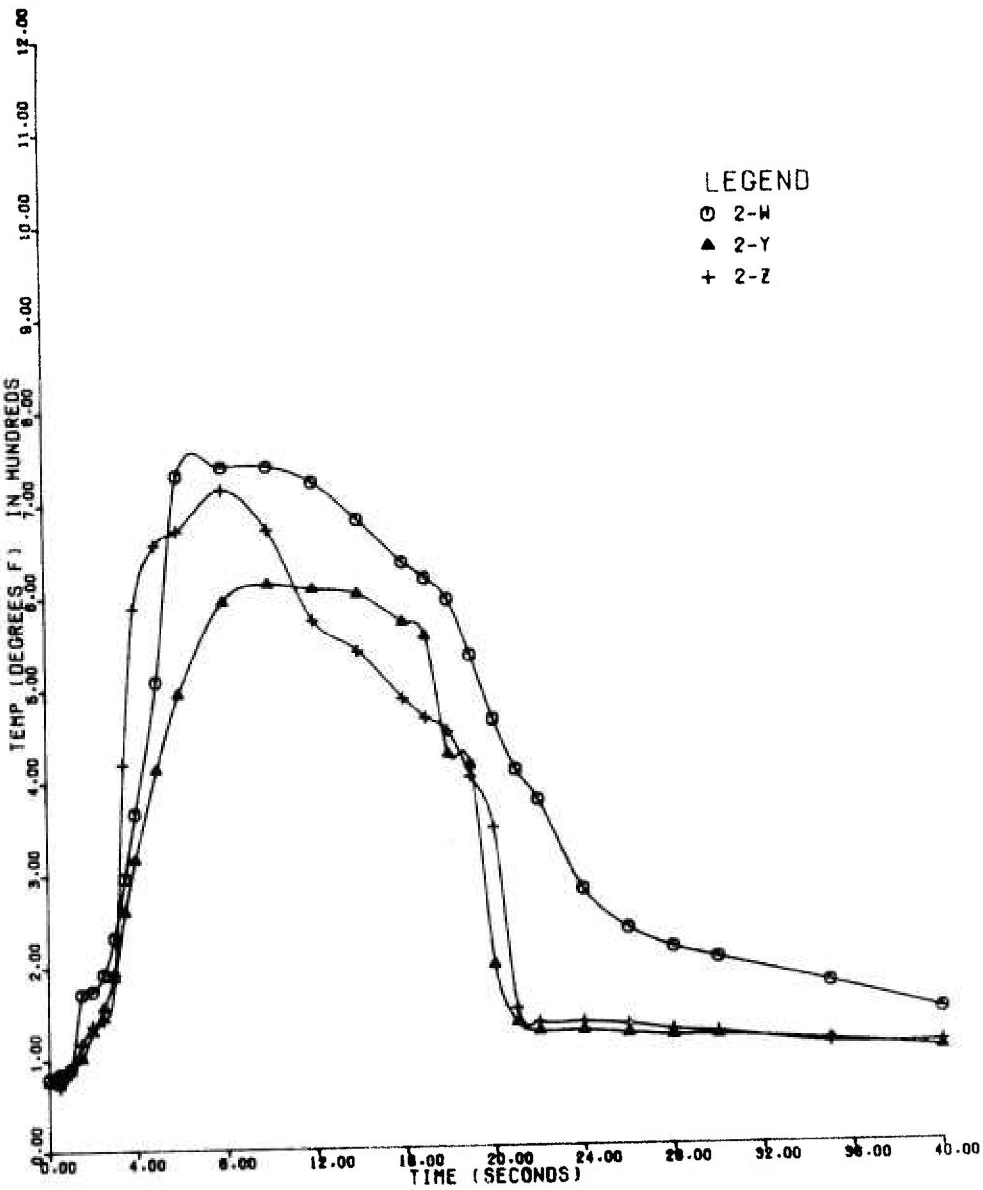


FIGURE C-7

CVA Magazine Test

No. 4

27 September 1973

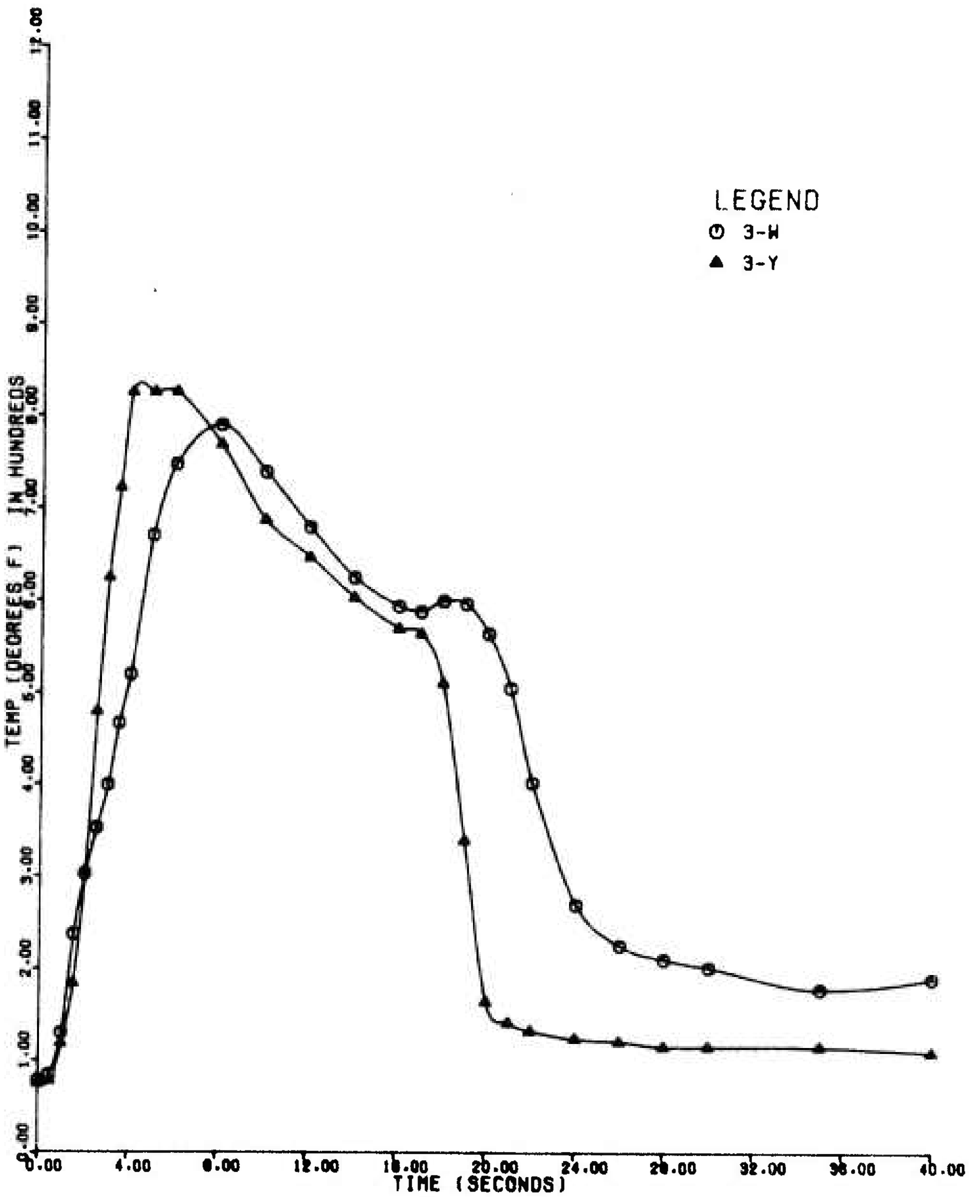


FIGURE C-8

CVA Magazine Test

No. 4

27 September 1973

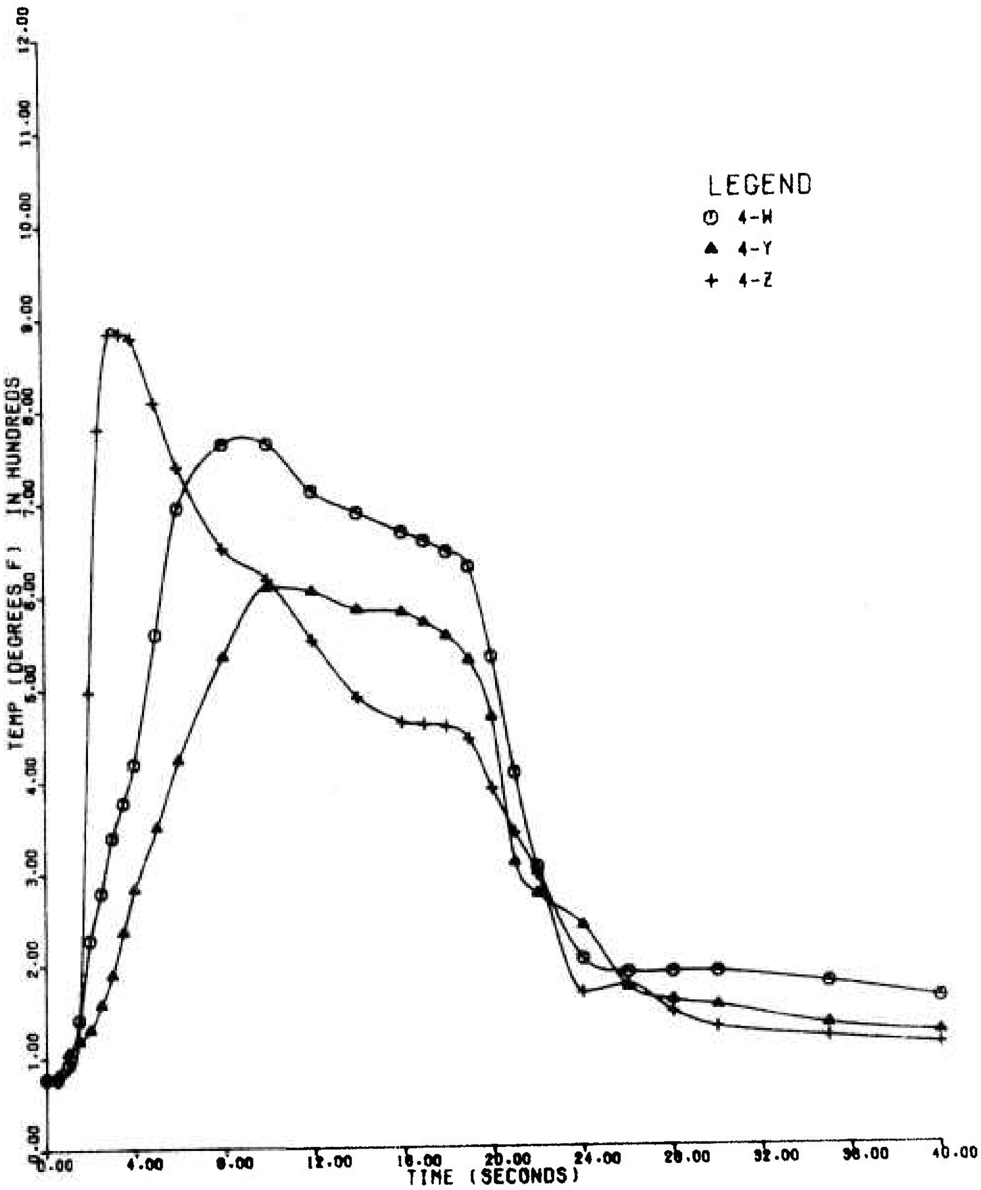


FIGURE C-9

CVA Magazine Test

No. 4

27 September 1973

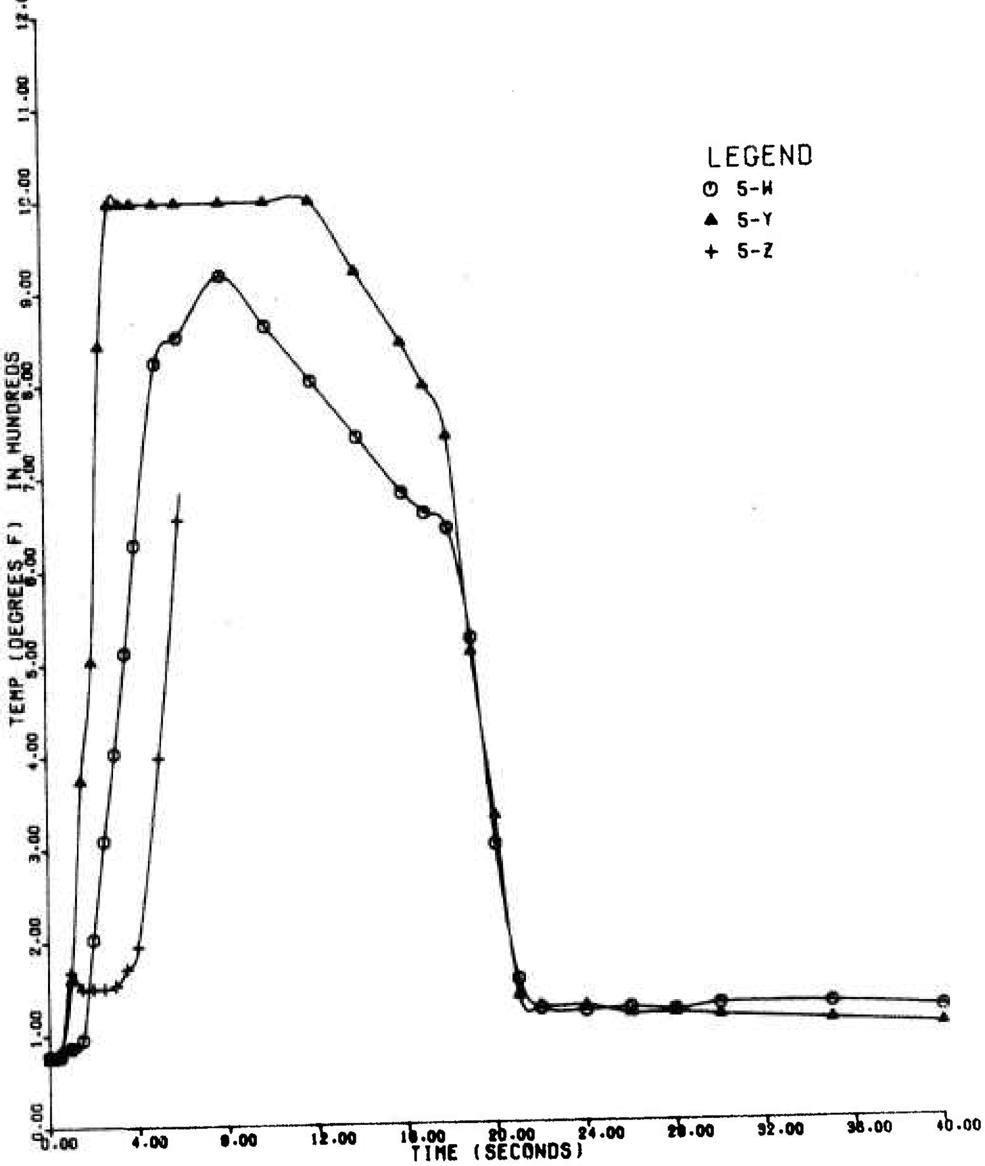


FIGURE C-10

CVA Magazine Test

No. 4

27 September 1973

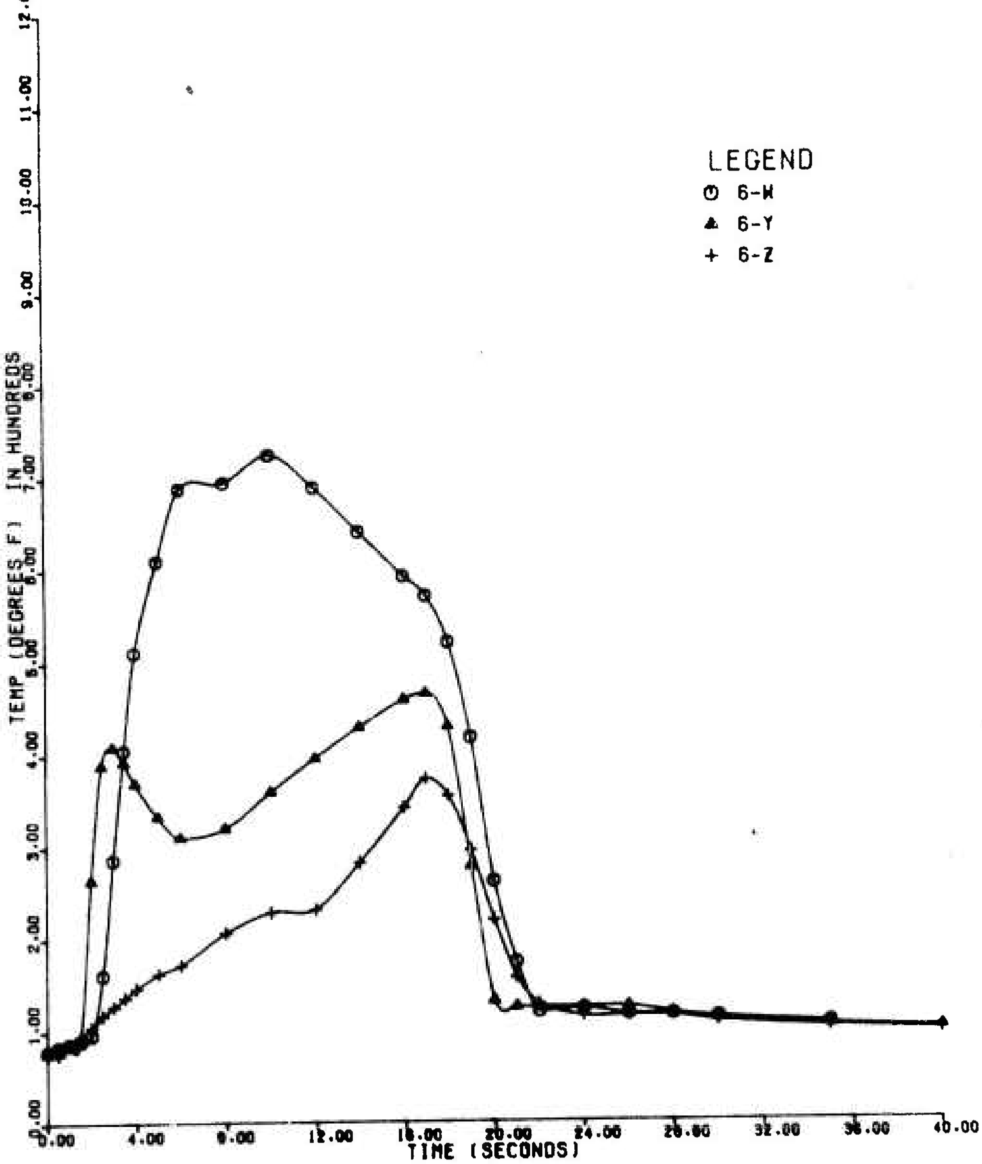


FIGURE C-11

CVA Magazine Test

No. 4

27 September 1973

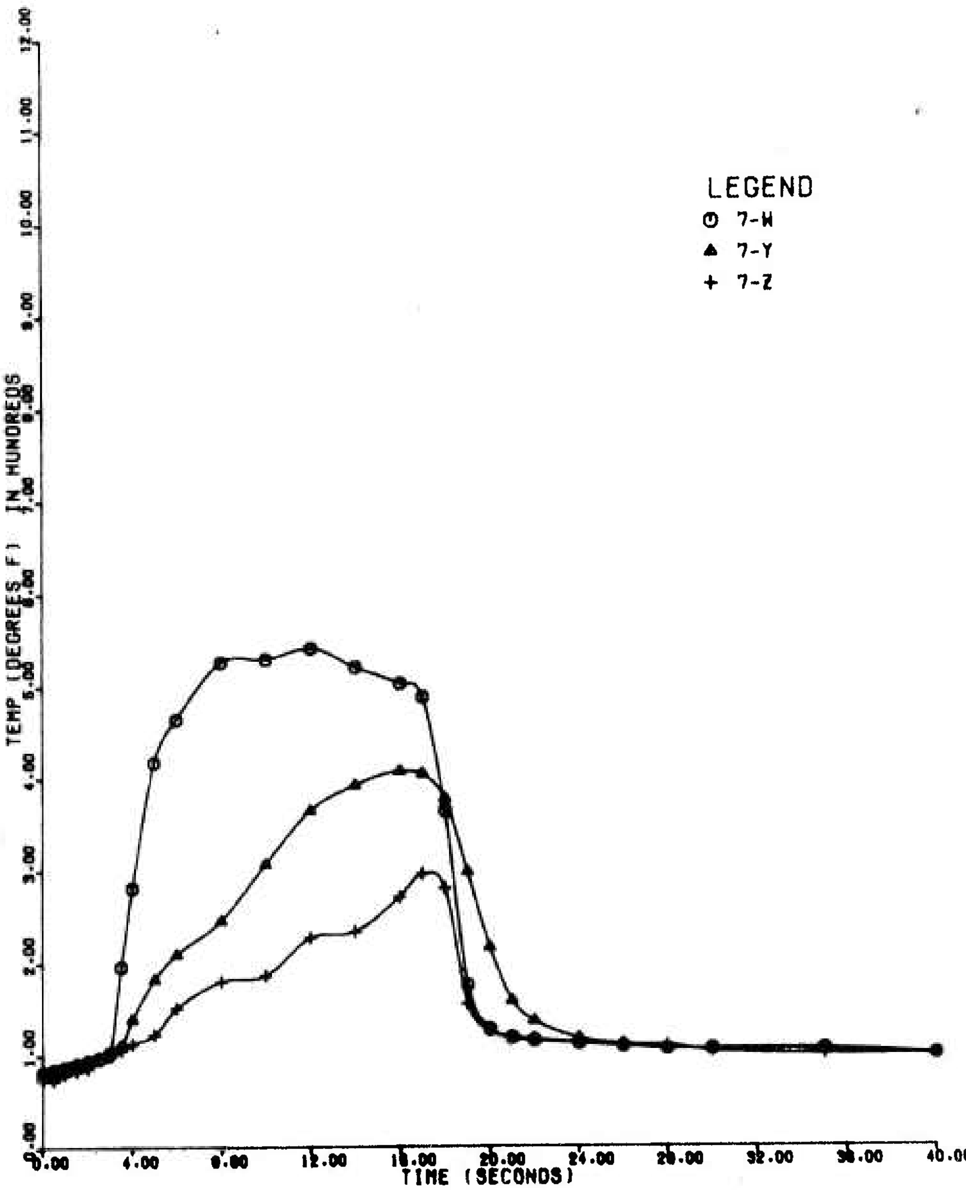


FIGURE C-12

CVA Magazine Test

No. 4 27 September 1973

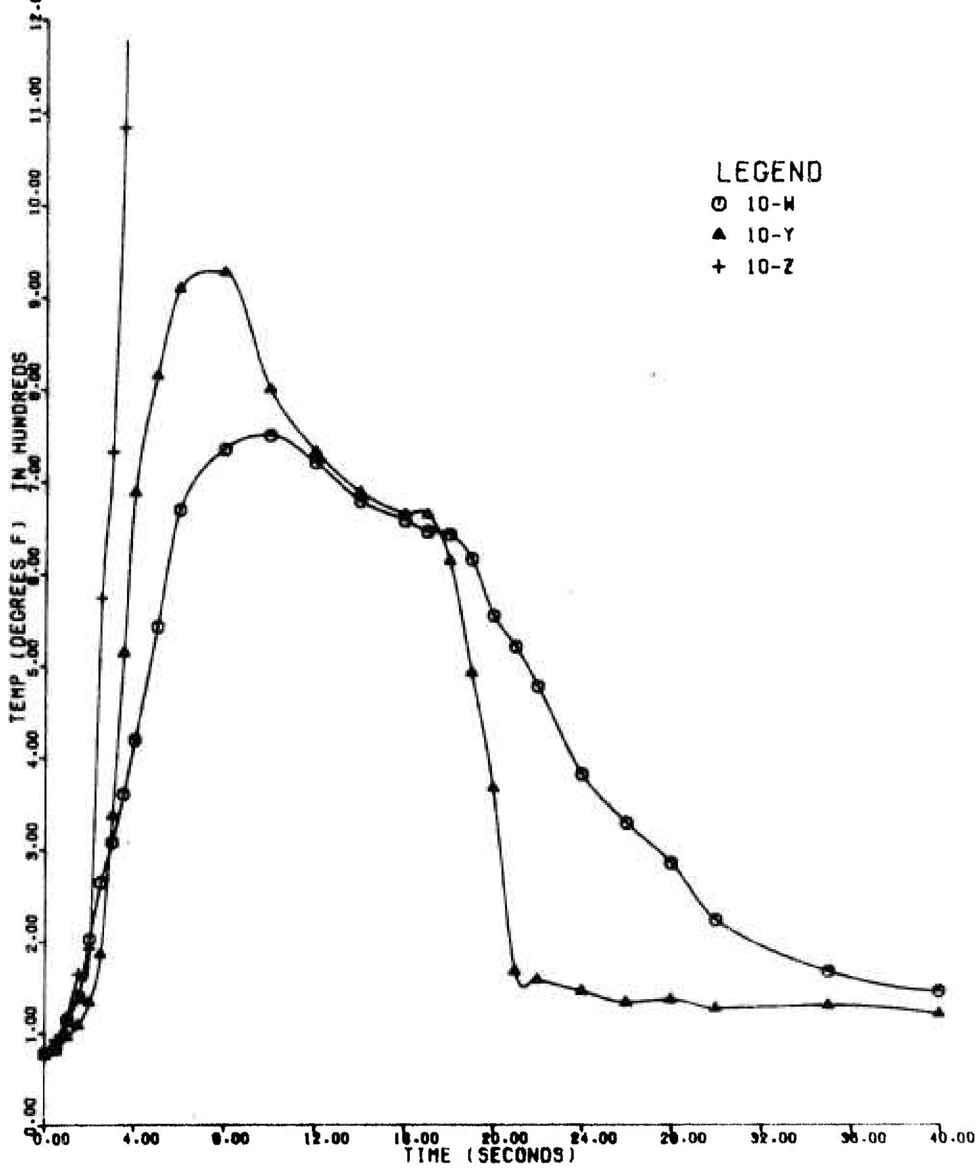


FIGURE C-13

CVA Magazine Test

No. 4 27 September 1973

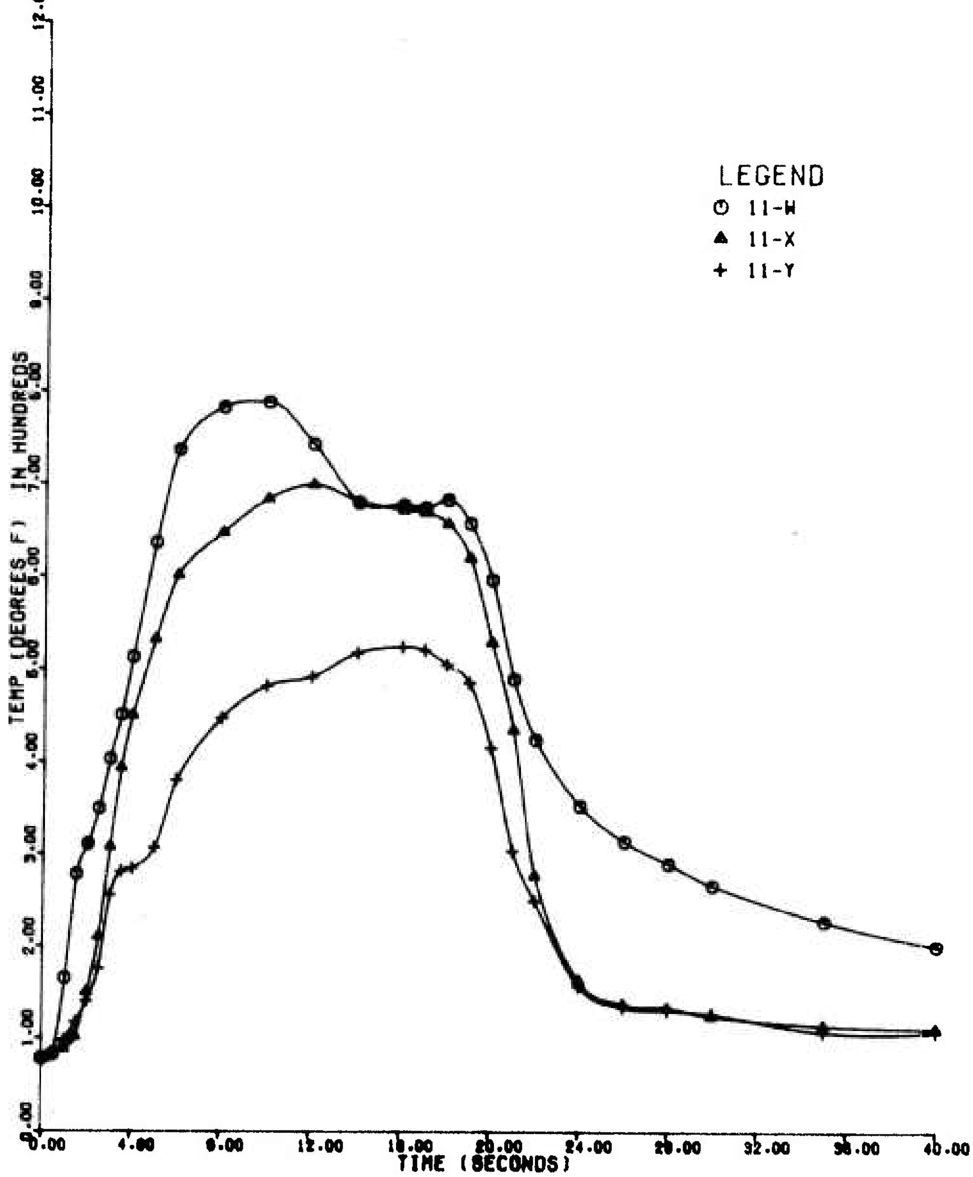


FIGURE C-14

CVA Magazine Test

No. 4 27 September 1973

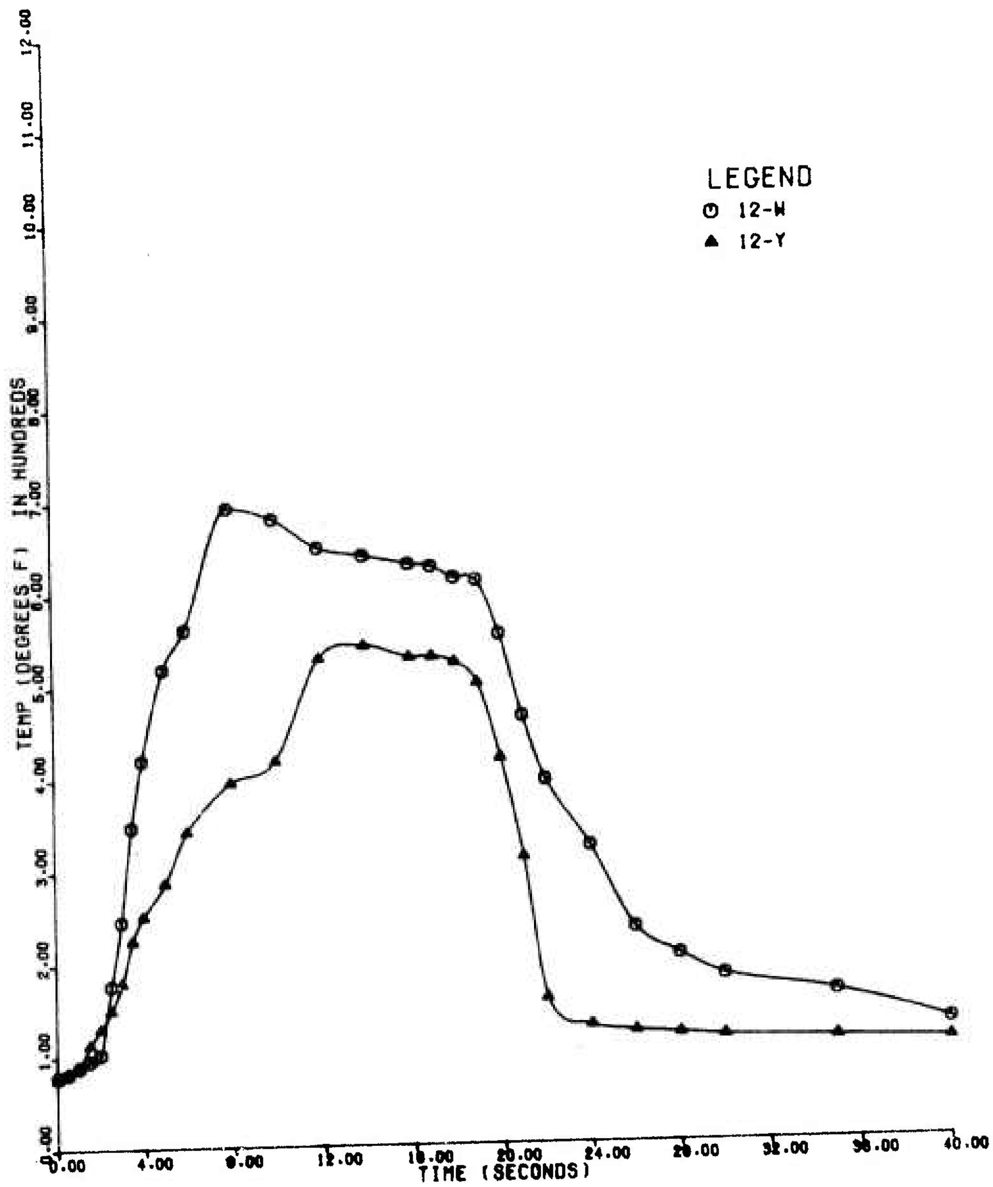


FIGURE C-15

No. 4 CVA Magazine Test 27 September 1973

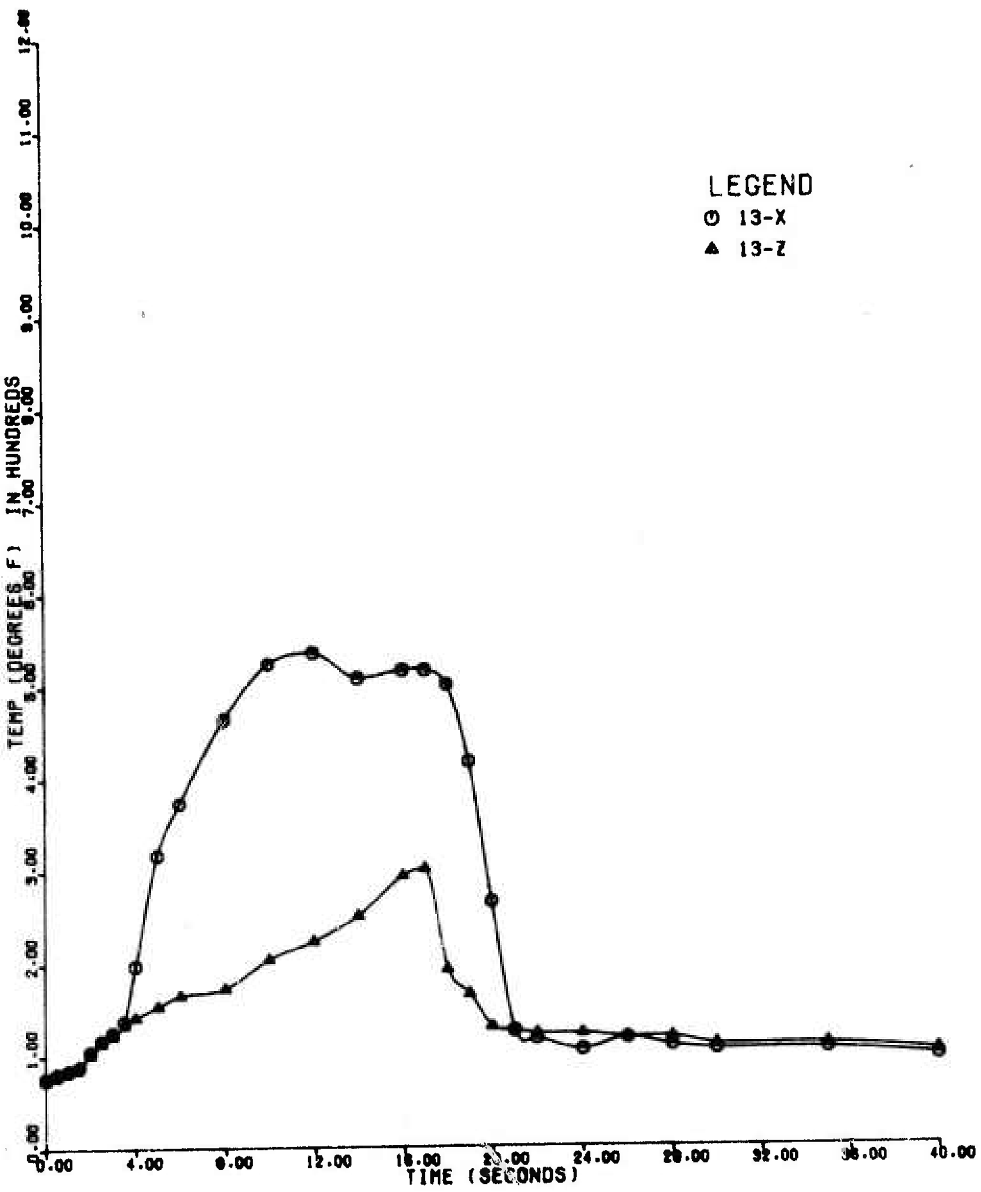


FIGURE C-16

CVA Magazine Test

No. 4

27 September 1973

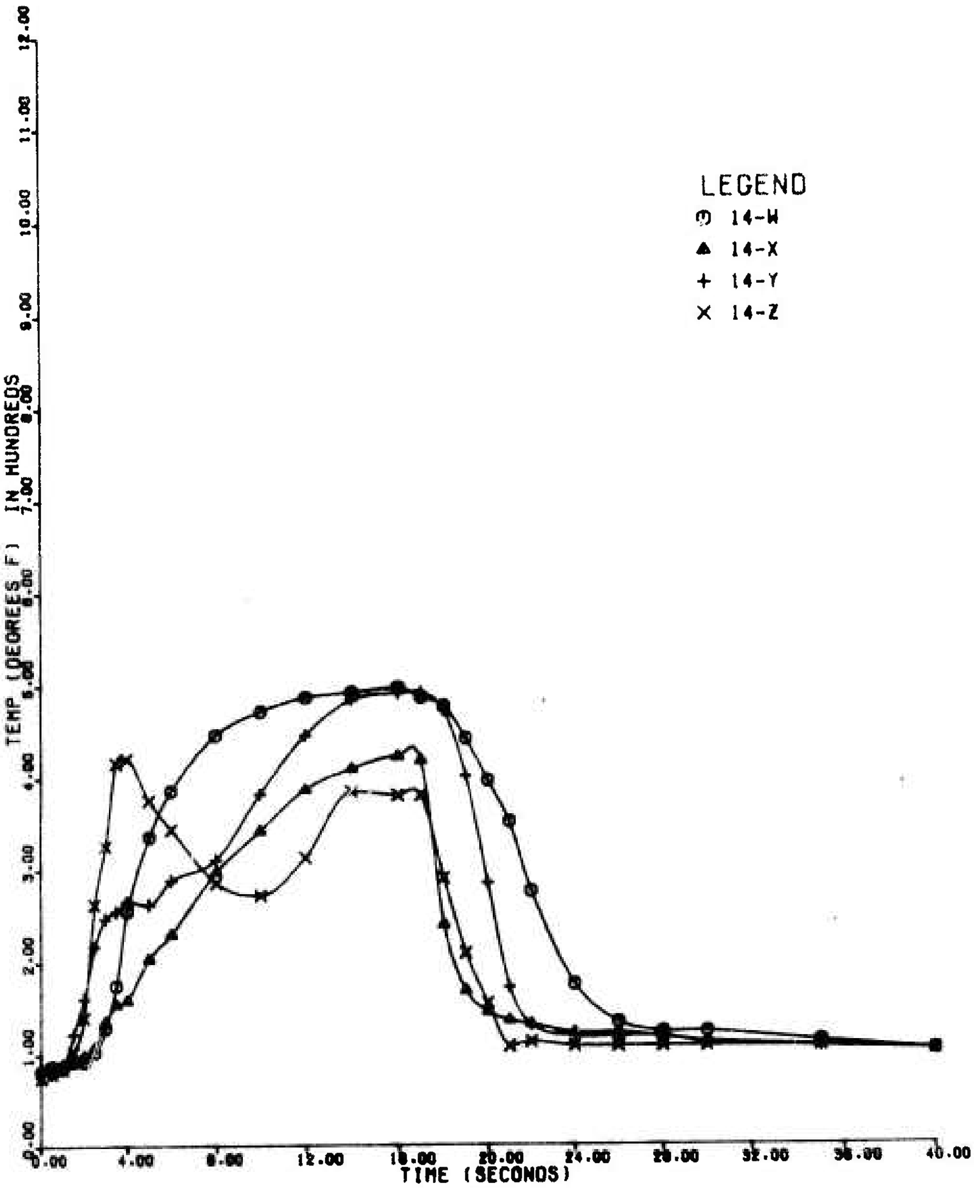


FIGURE C-17

CVA Magazine Test

No. 4

27 September 1973

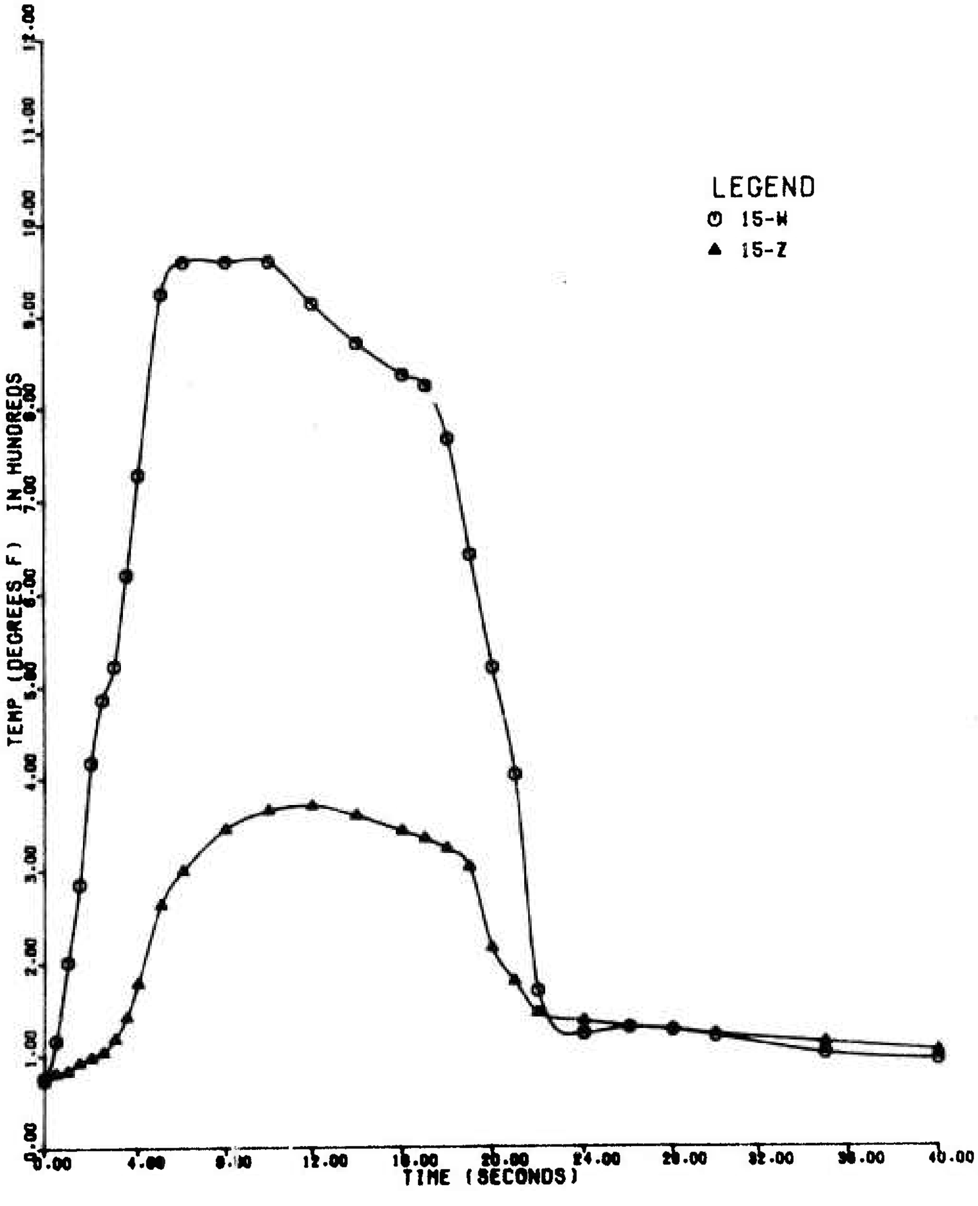


FIGURE C-18

CVA Magazine Test

No. 4

27 September 1973

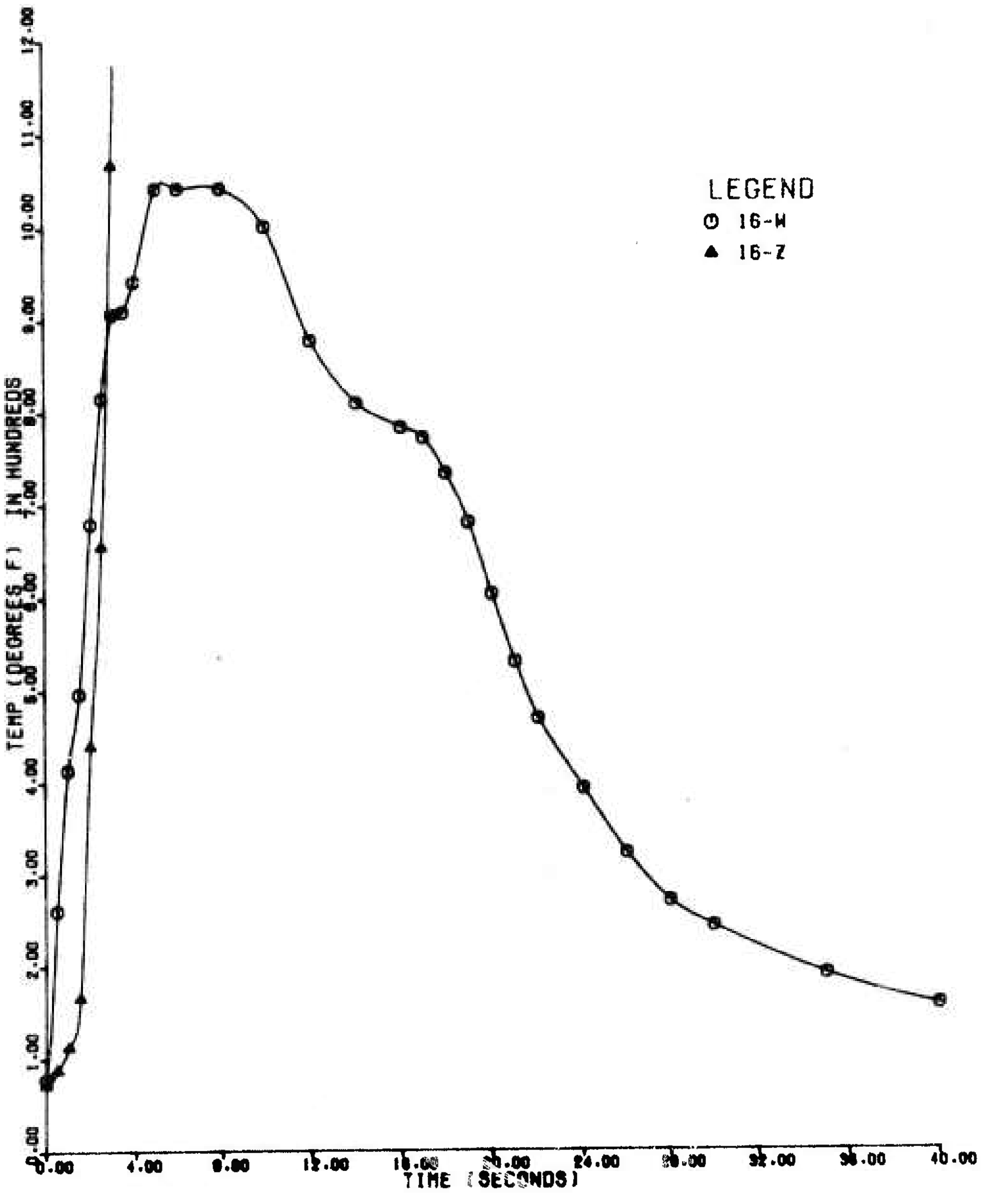


FIGURE C-19

CVA Magazine Test

No. 4

27 September 1973

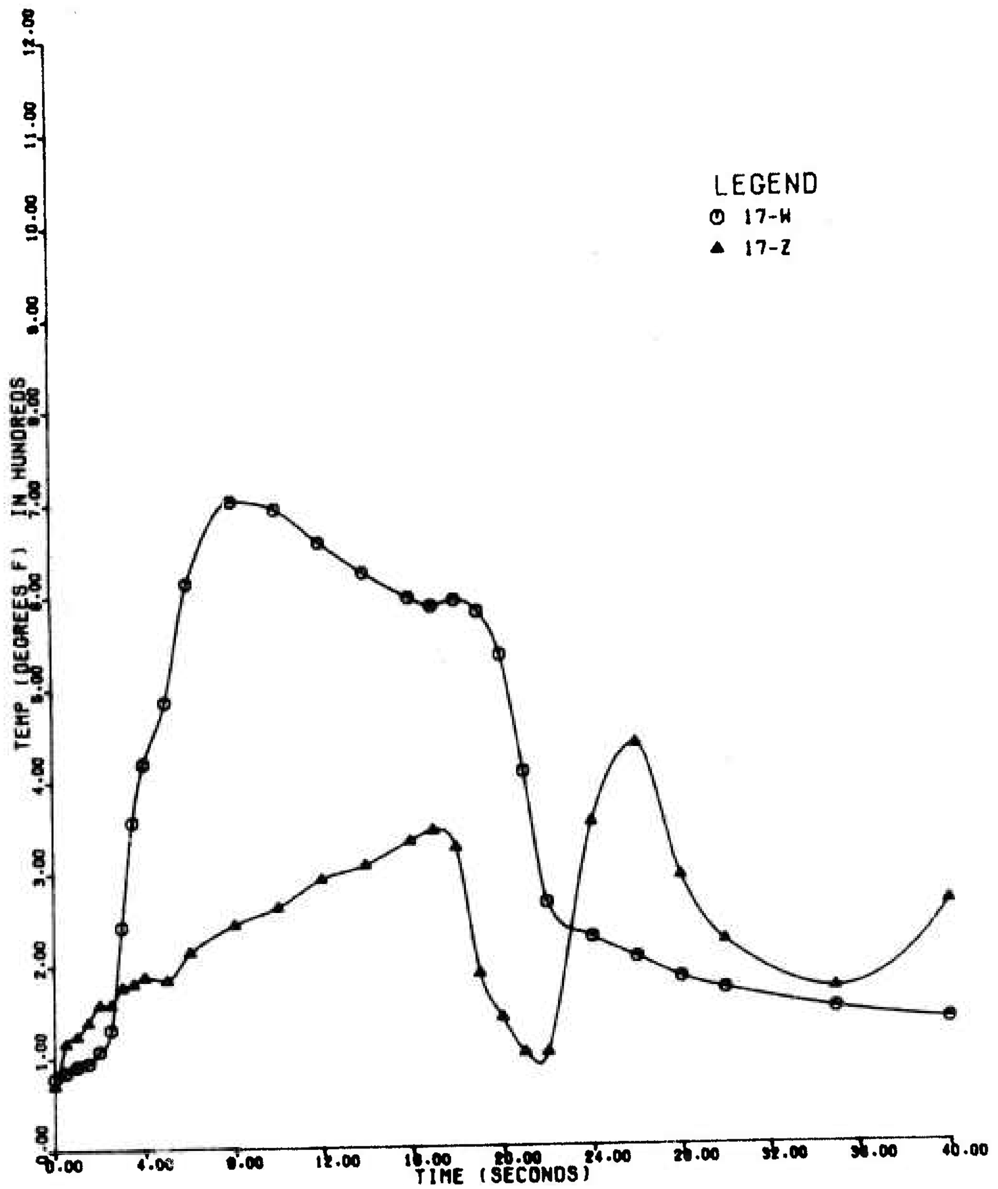


FIGURE C-20

CVA Magazine Test

No. 4

27 September 1973

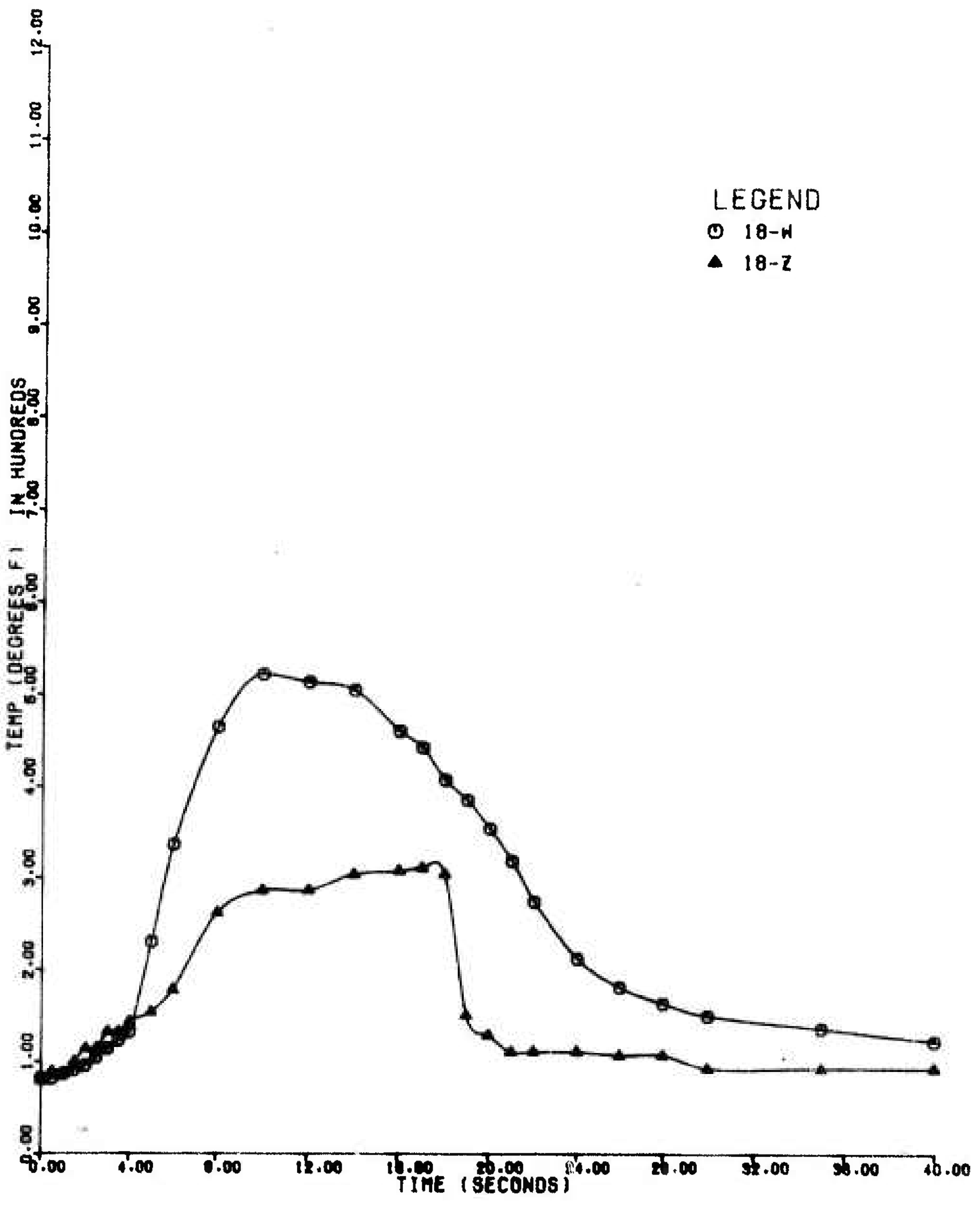


FIGURE C-21

CVA Magazine Test

No. 4 27 September 1973

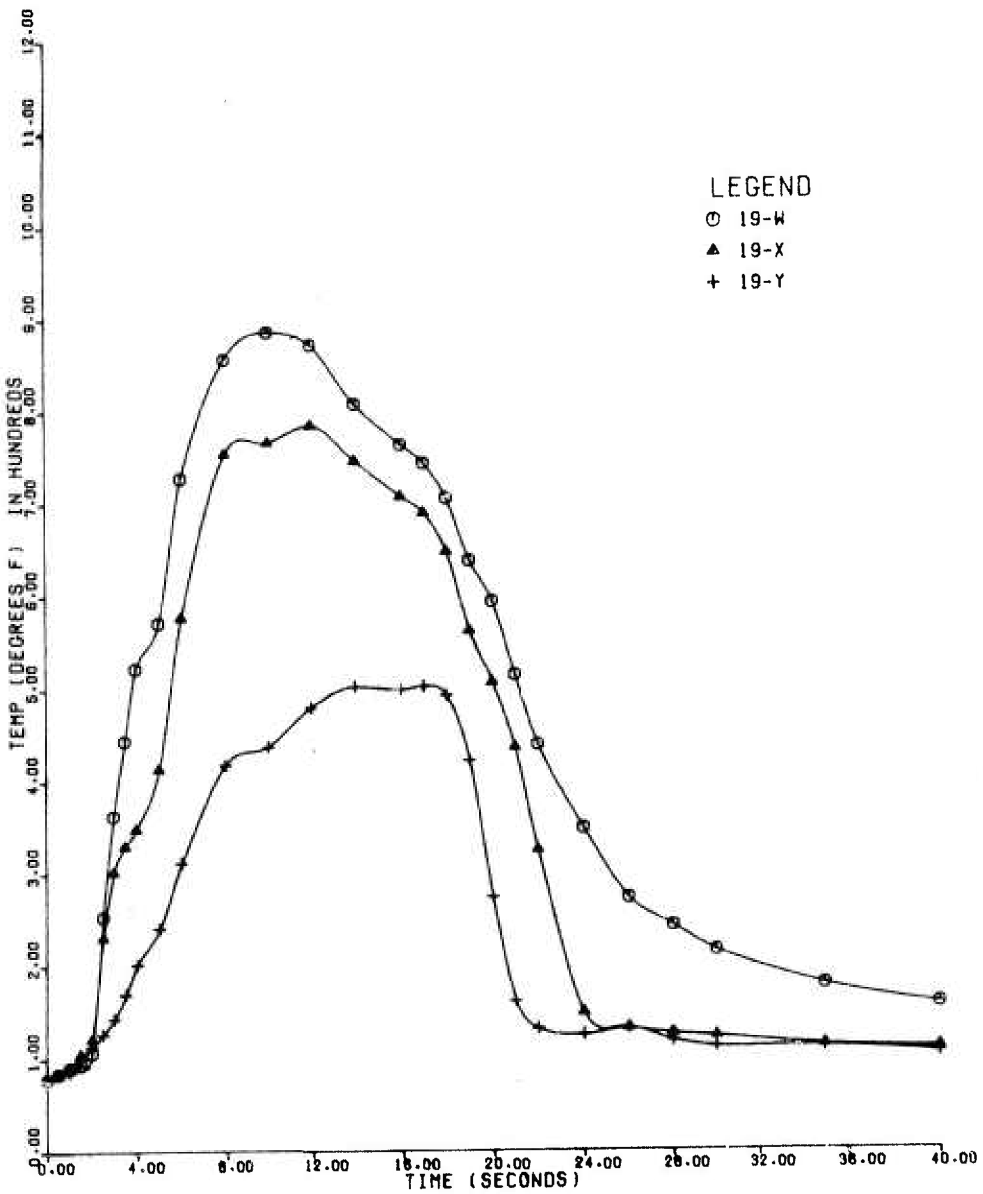


FIGURE C-22

CVA Magazine Test

No. 4 **27 September 1973**

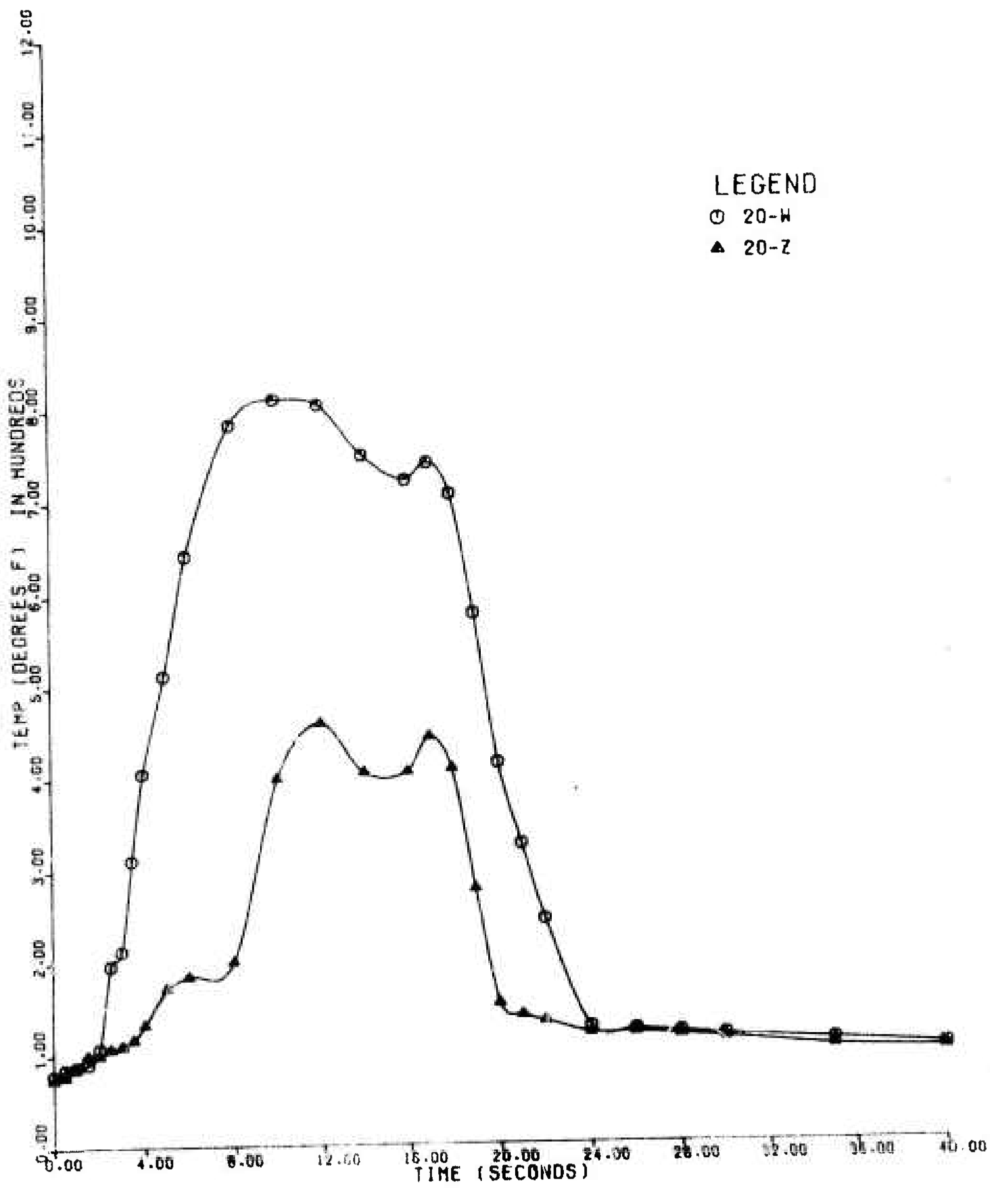


FIGURE C-23

CVA Magazine Test

No. 4

September 1973

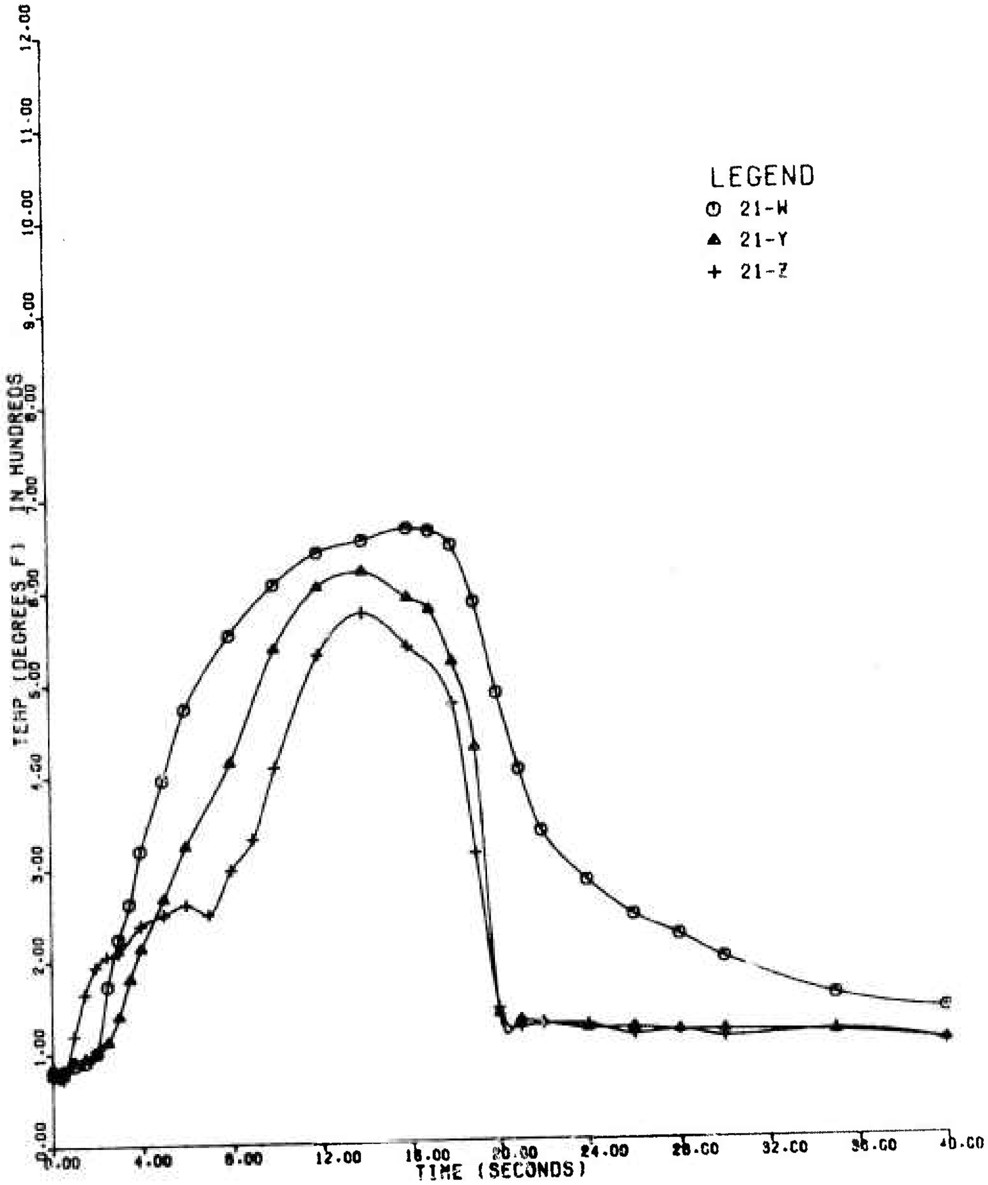


FIGURE C-24

CVA Magazine Test

No. 4

27 September 1973

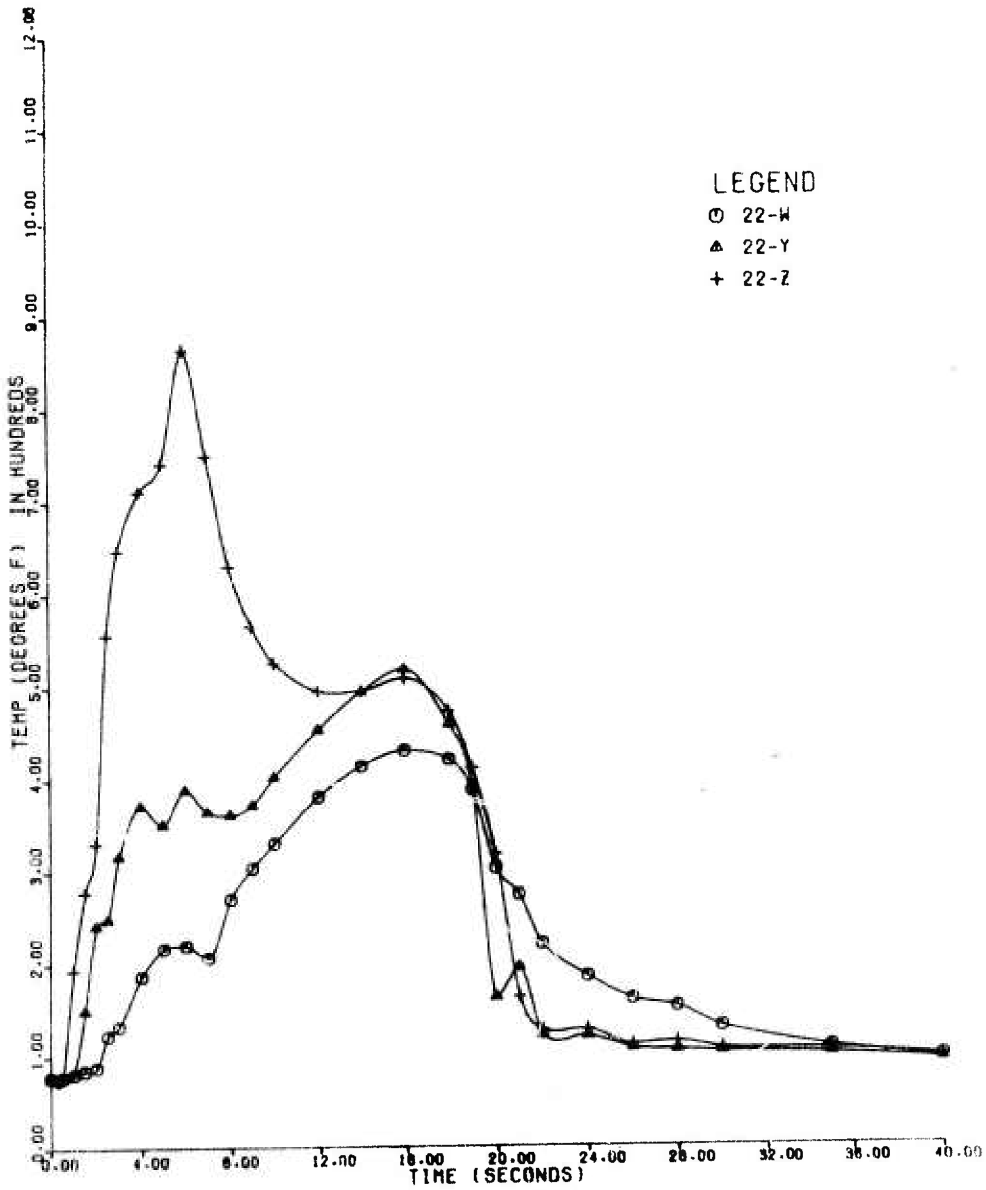


FIGURE C-25

CVA Magazine Test

No. 4

27 September 1973

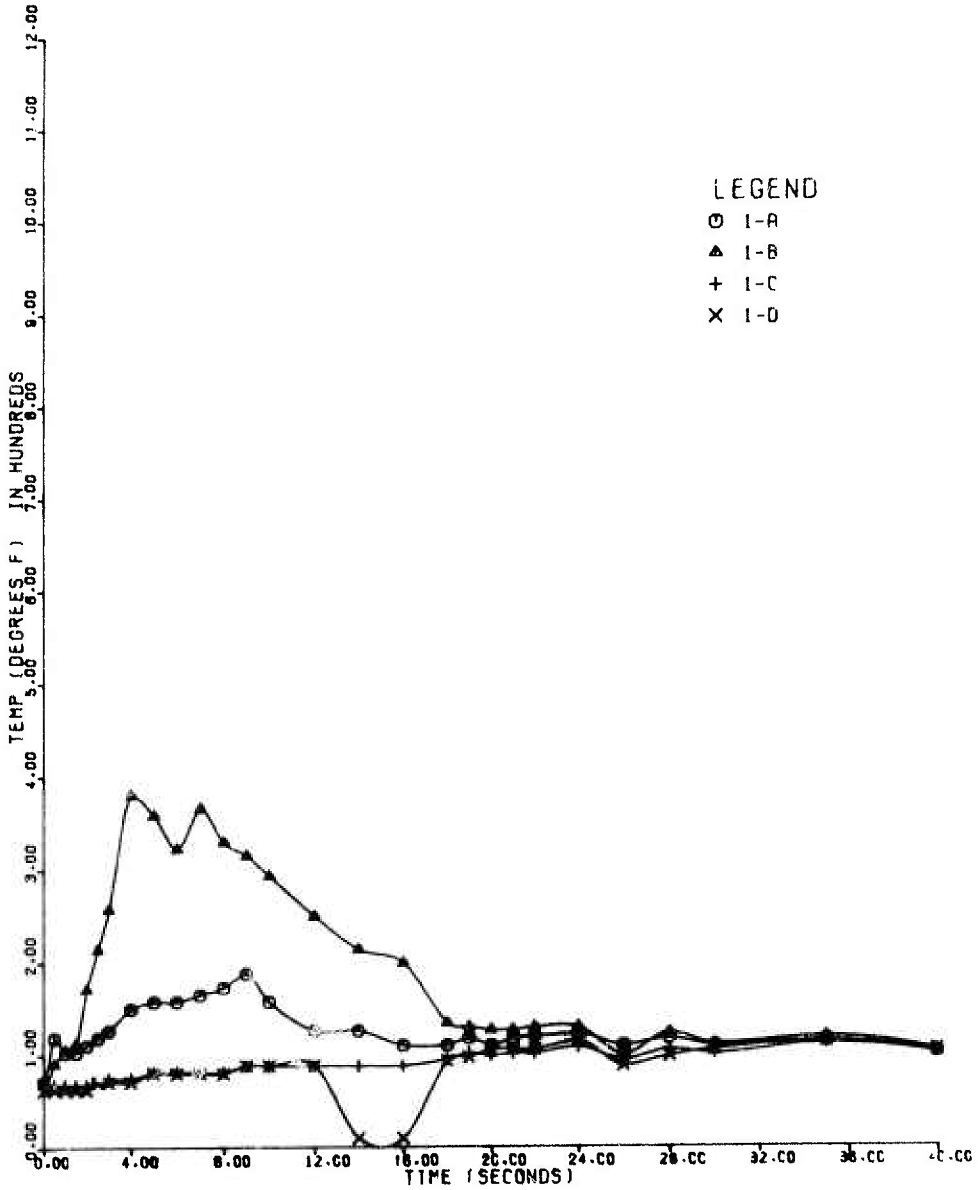


FIGURE C-26

CVA Magazine Test

No. 4 **27 September 1973**

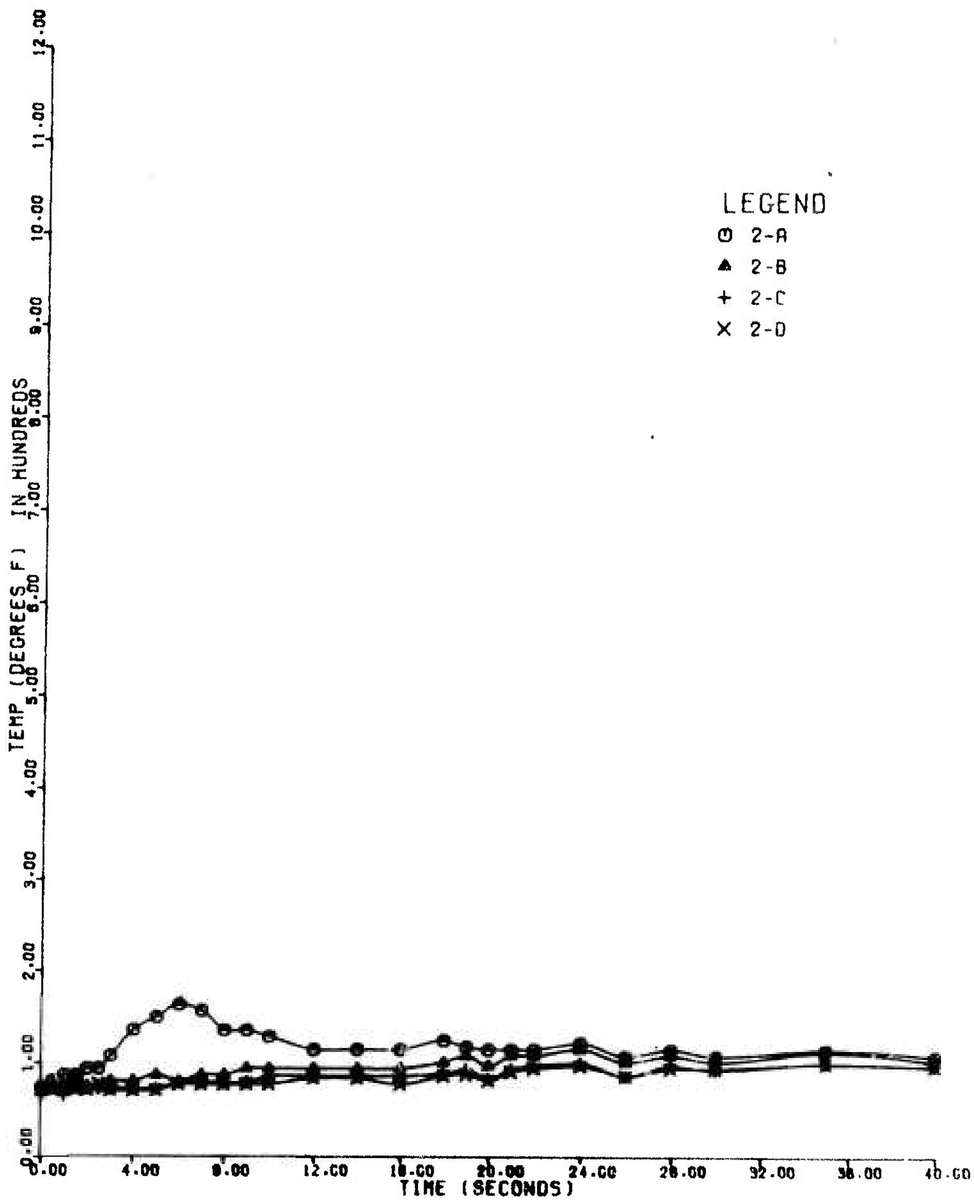


FIGURE C-27

CVA Magazine Test

No. 4 27 September 1973

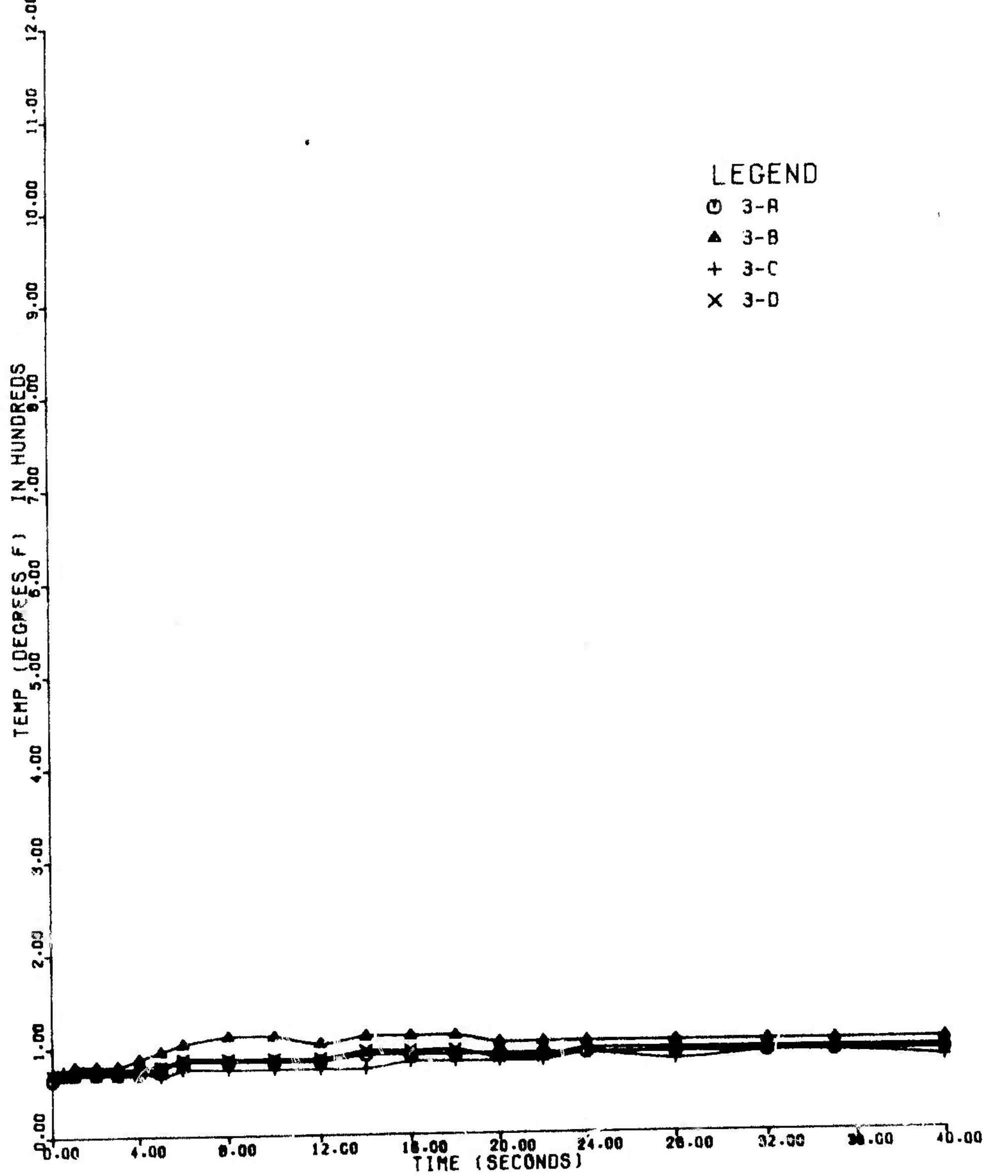


FIGURE C-28

CVA Magazine Test

No. 4

27 September 1973

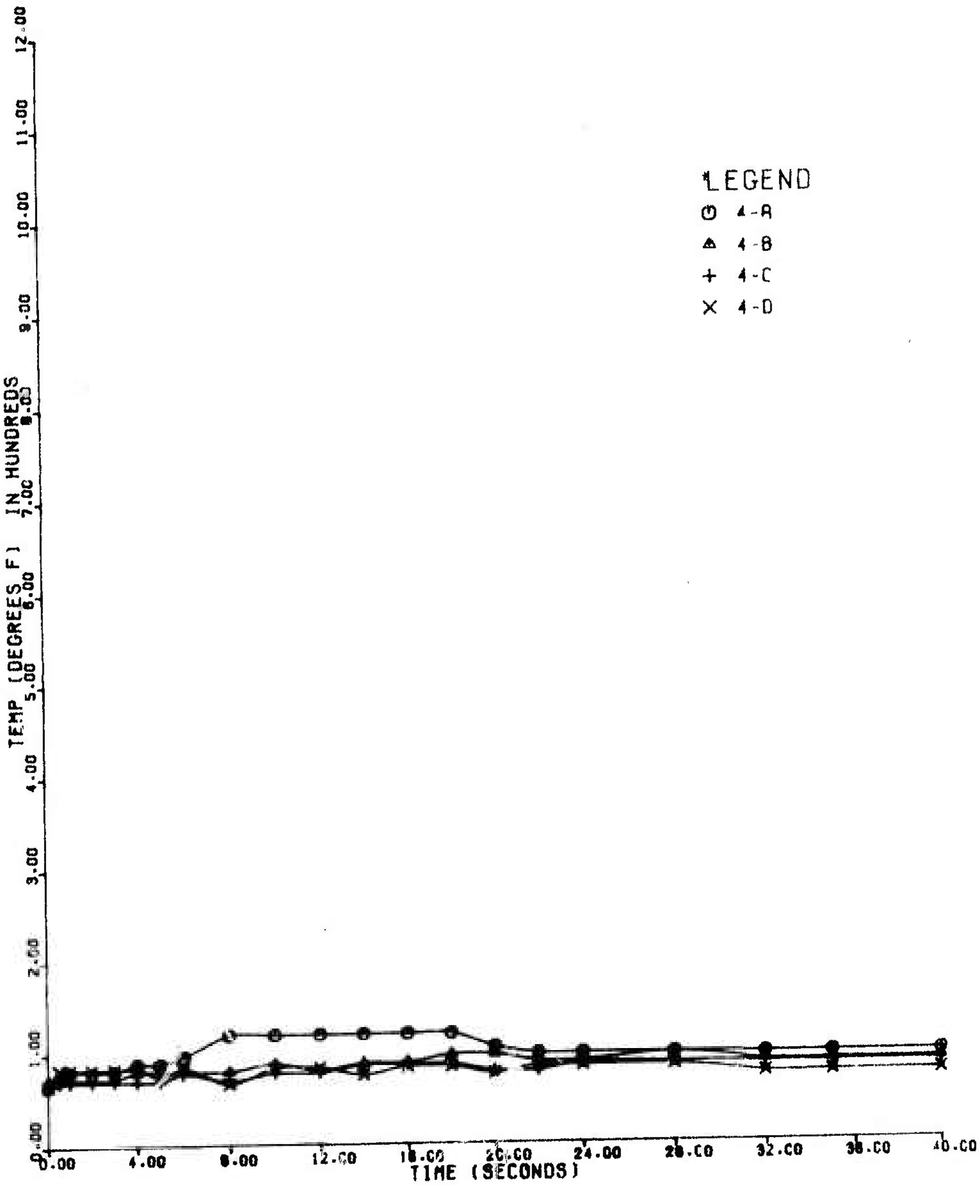


FIGURE C-29

CVA Magazine Test

No. 4

27 September 1973

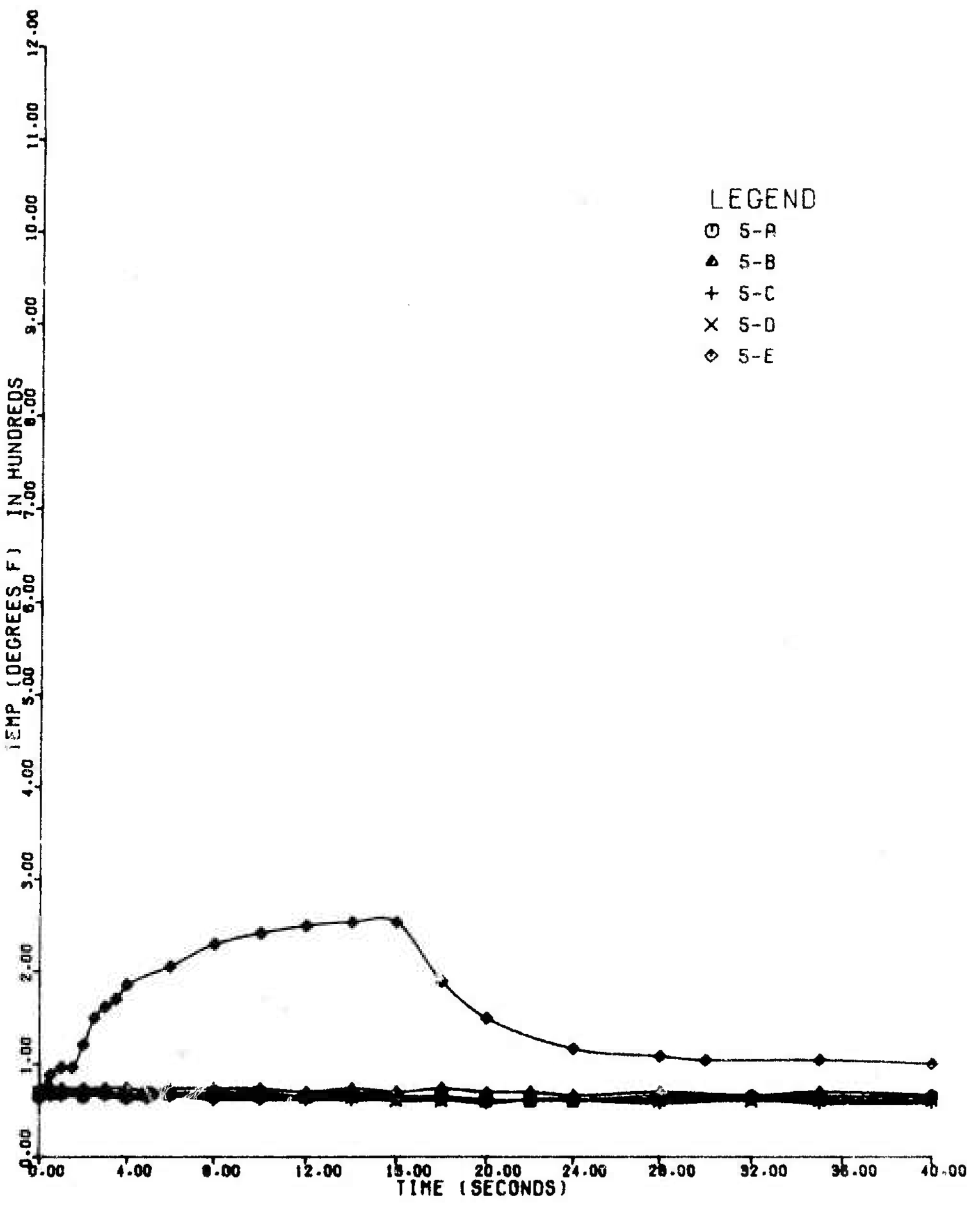


FIGURE C-30

CVA Magazine Test

No. 4 **27 September 1973**

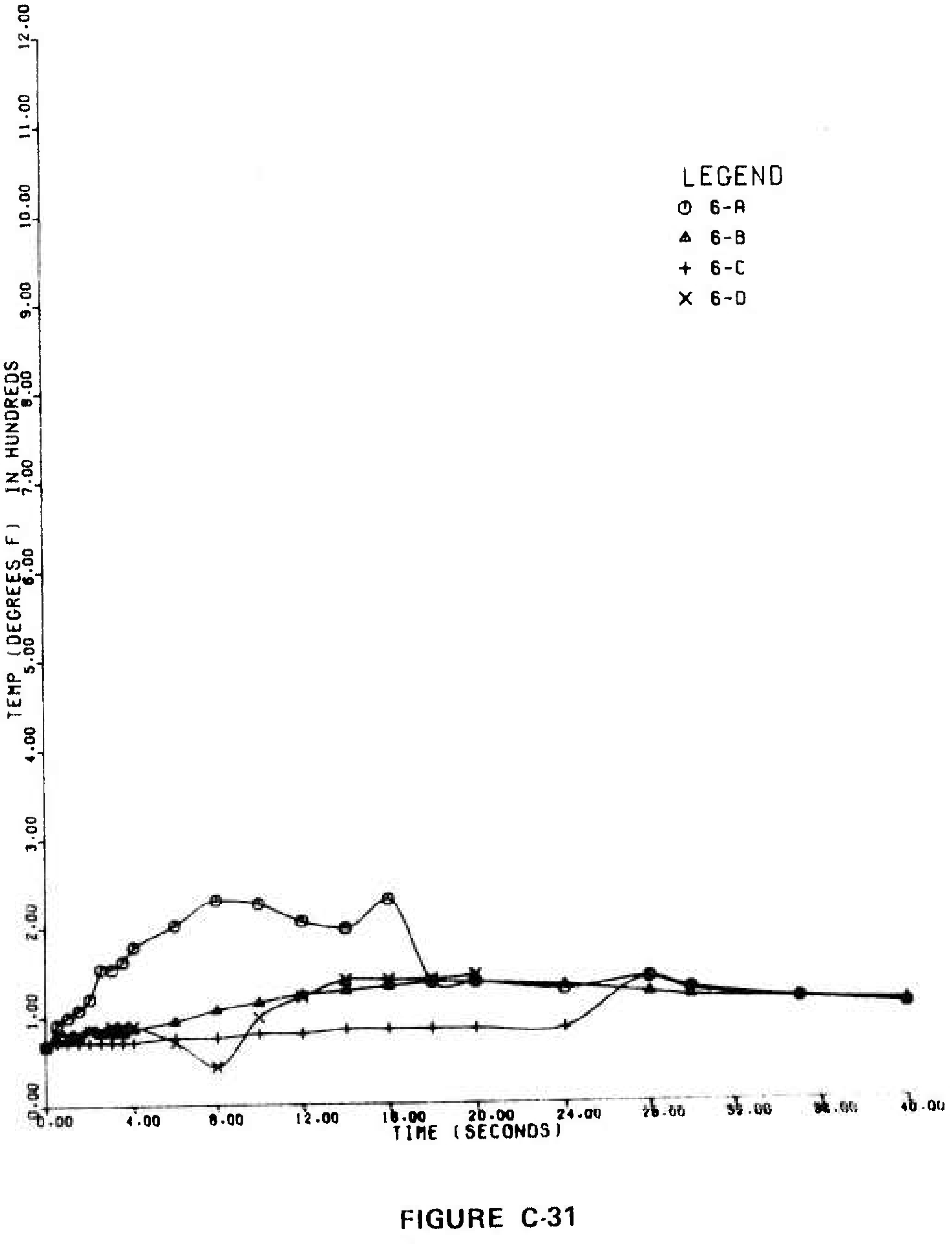


FIGURE C-31

CVA Magazine Test

No. 4

27 September 1973

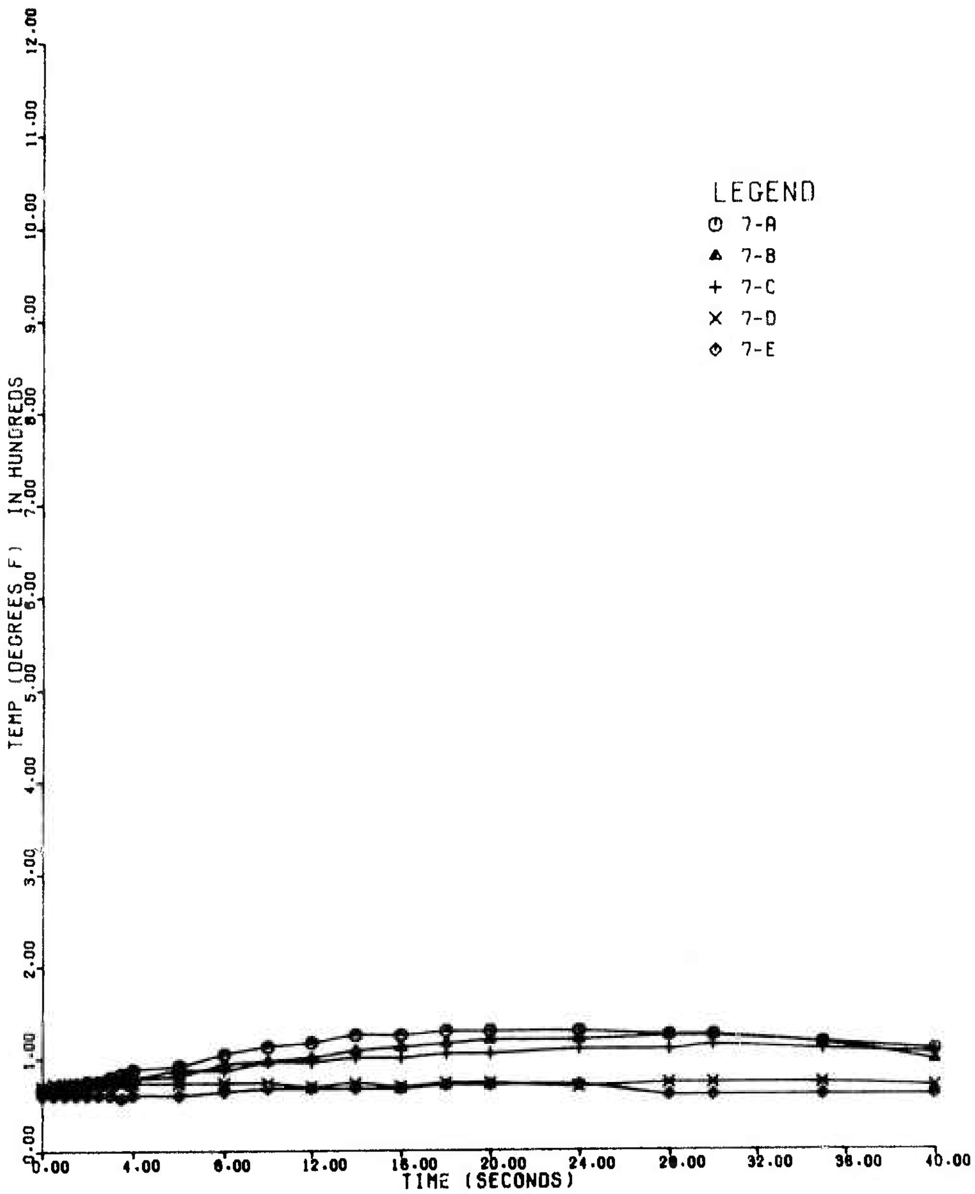


FIGURE C-32

CVA Magazine Test

No. 4 **27 September 1973**

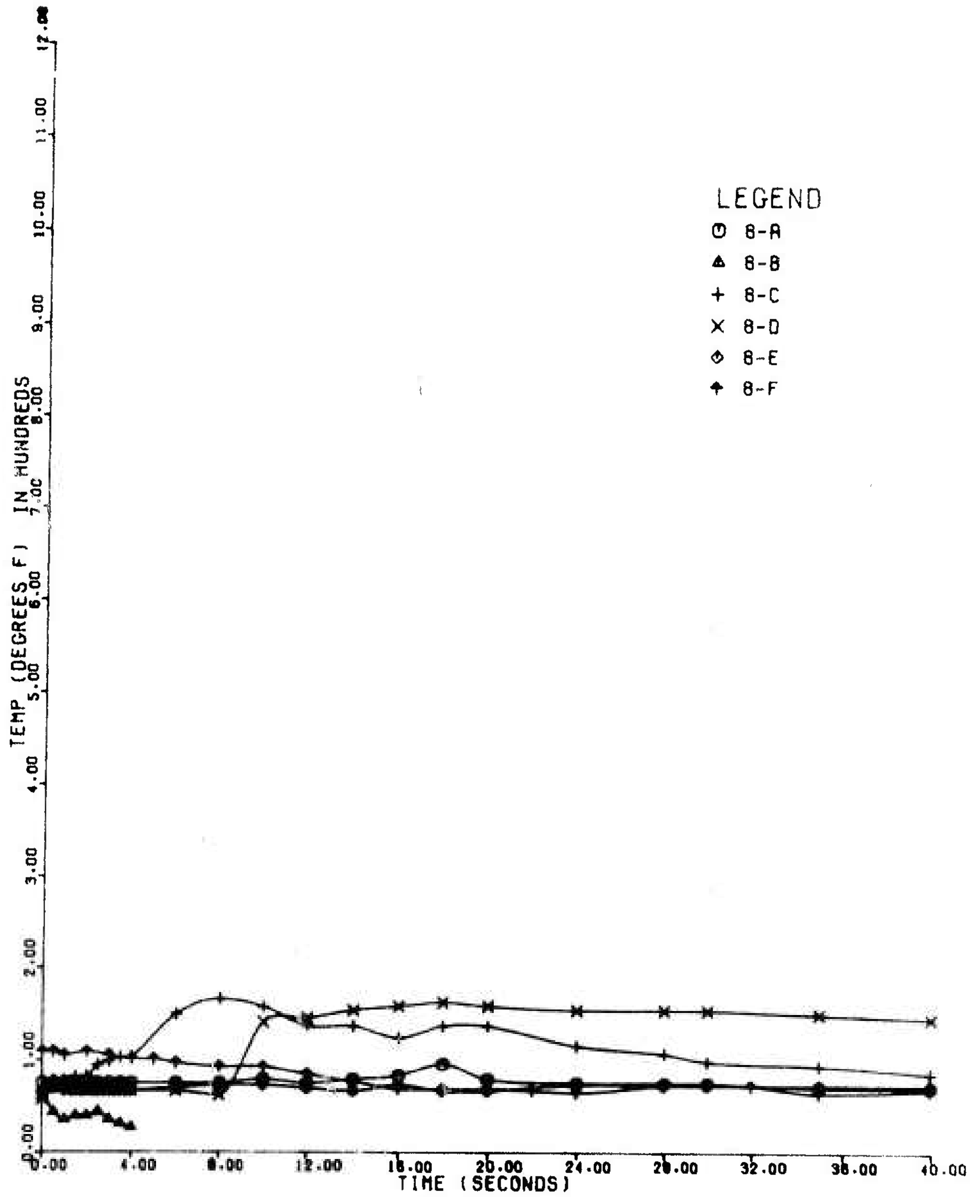


FIGURE C-33

CVA Magazine Test

No. 4

27 September 1973

APPENDIX D

TEST DATA OBTAINED DURING TEST NO. 5

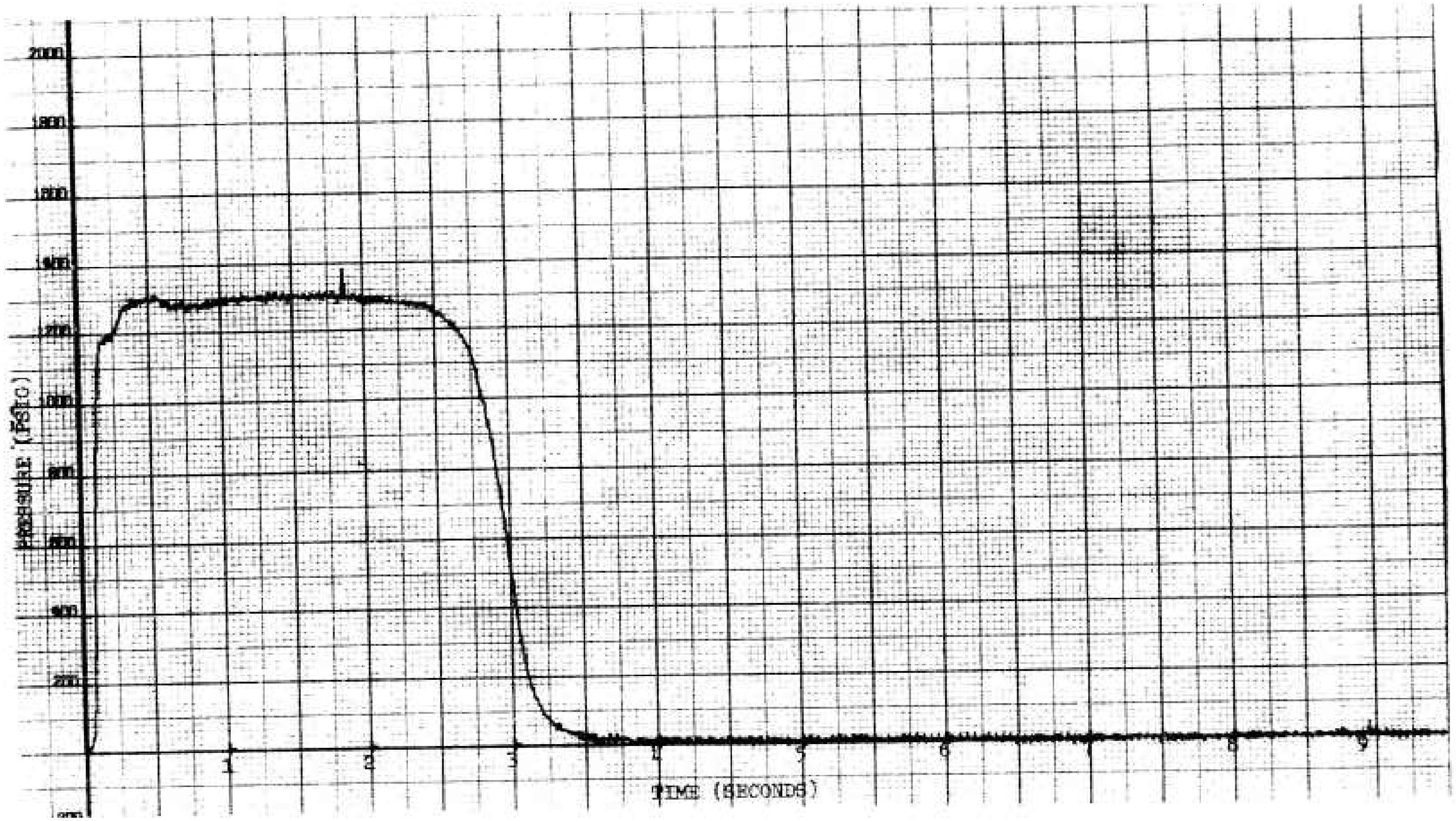


FIGURE D-1

SPARROW MK 38 MOD 1 Motor Pressure
Test No. 5

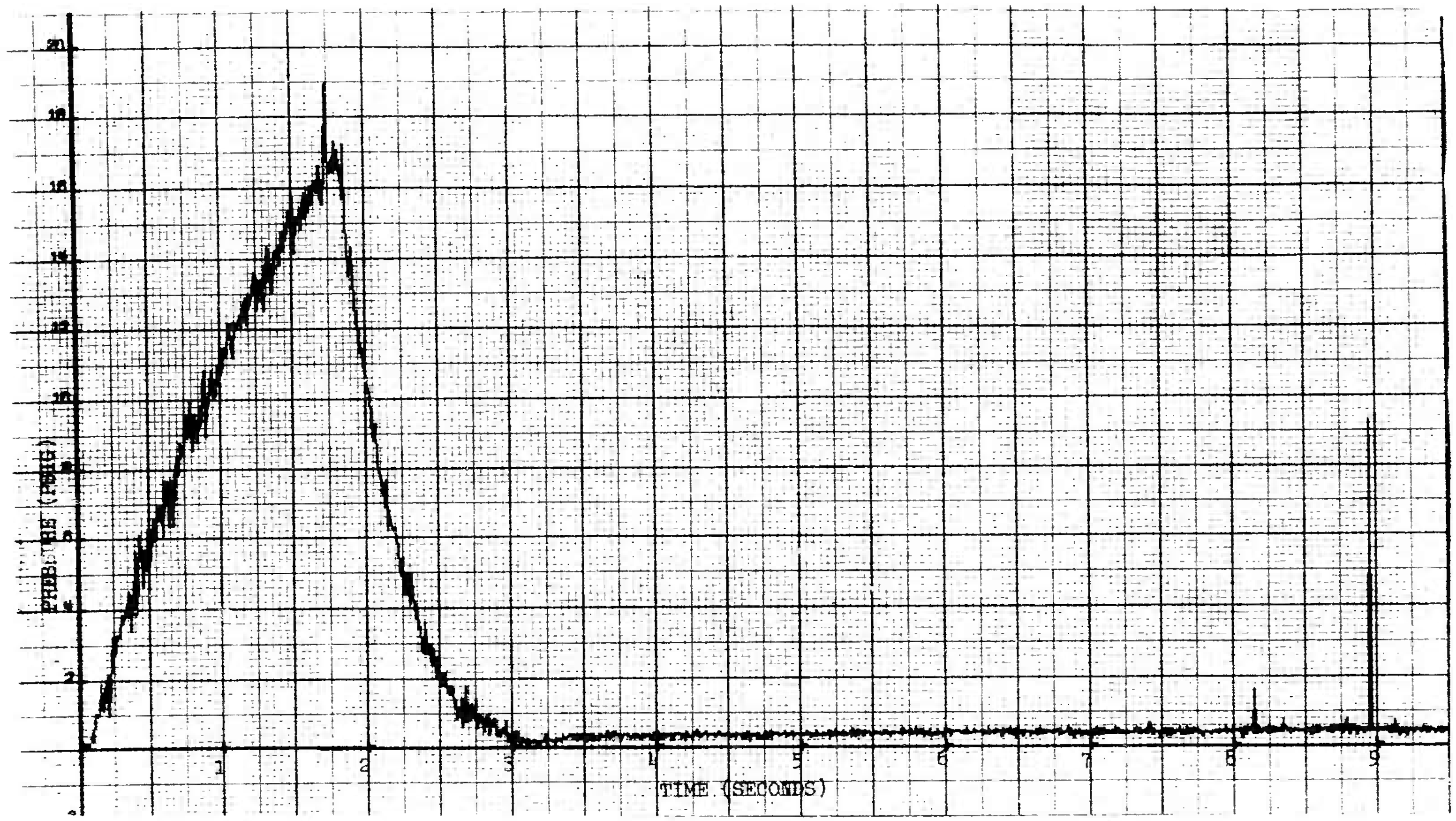


FIGURE D-2

Pressure Transducer No. 1
Test No. 5

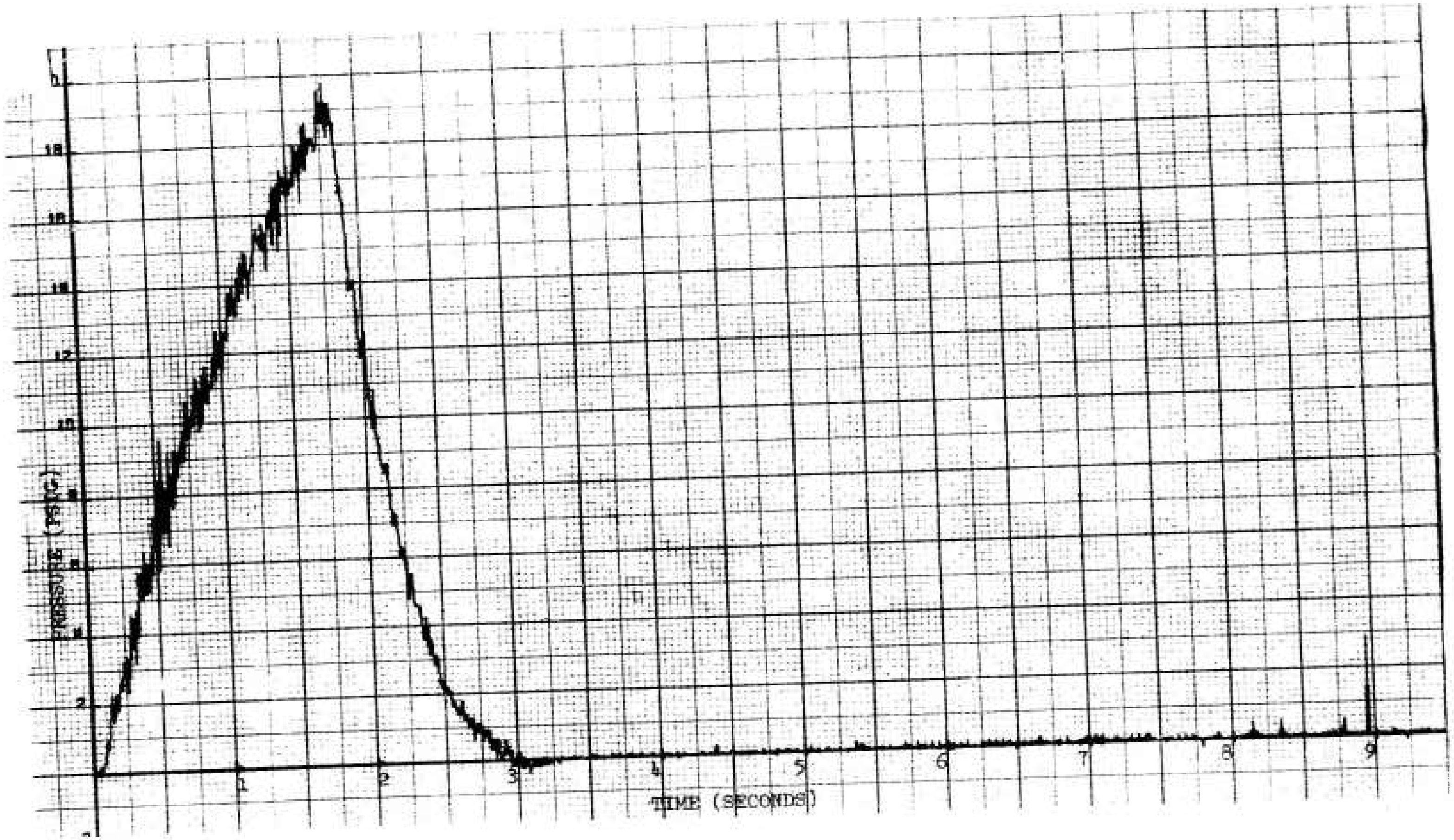


FIGURE D-3

Pressure Transducer No. 2
Test No. 5

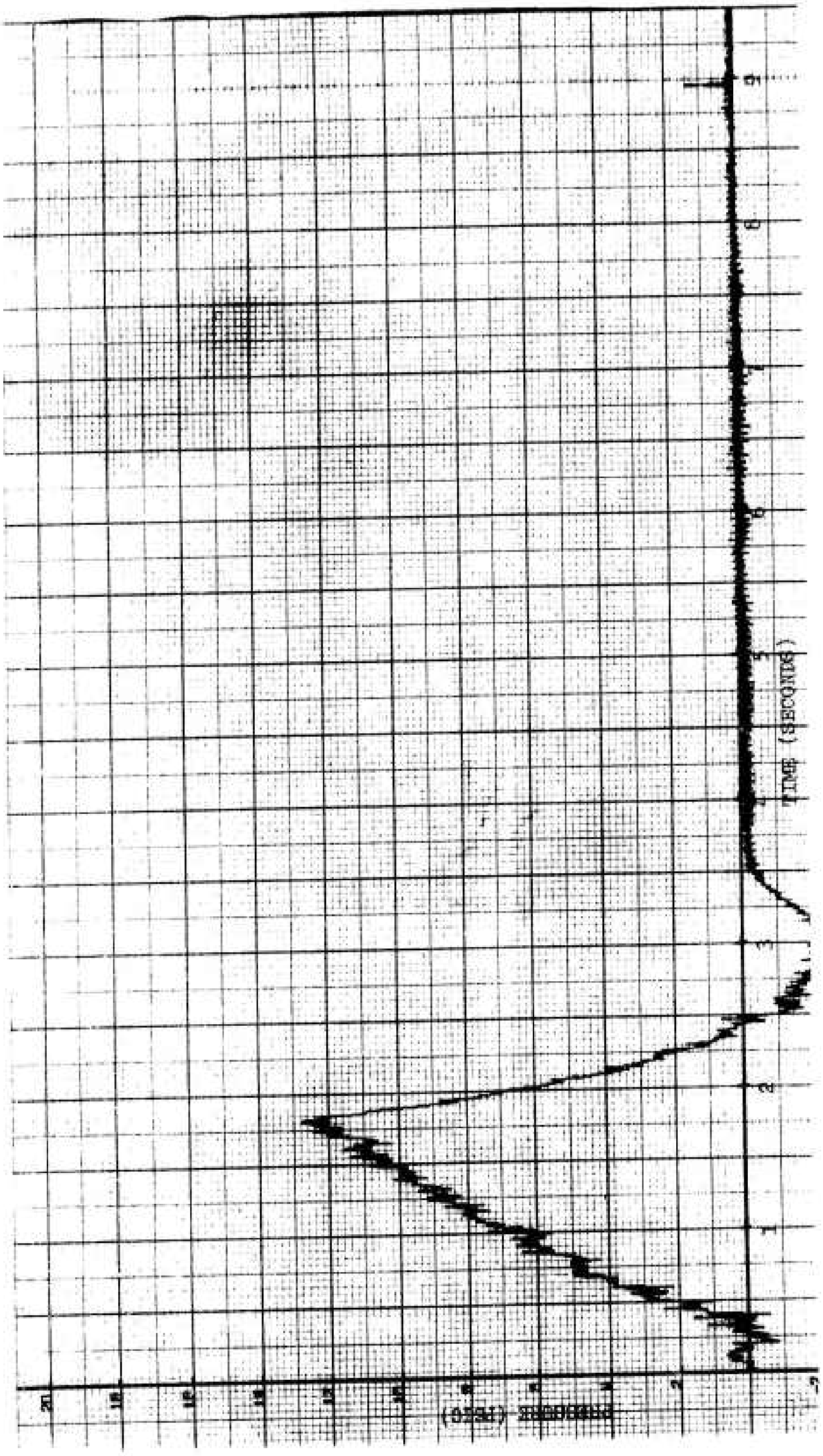


FIGURE D-4

Pressure Transducer No. 3
Test No. 5

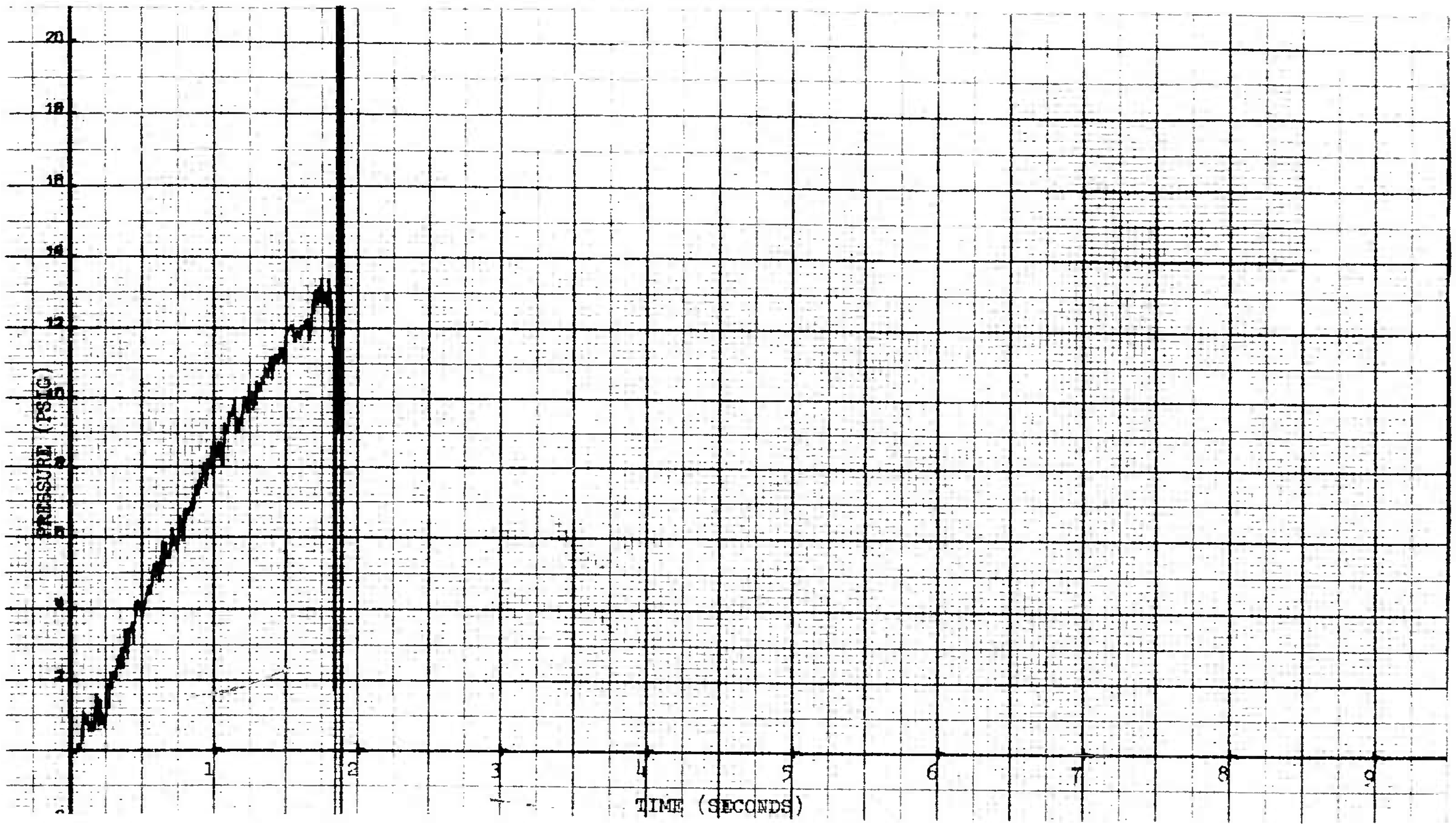


FIGURE D-5

Pressure Transducer No. 4
Test No. 5

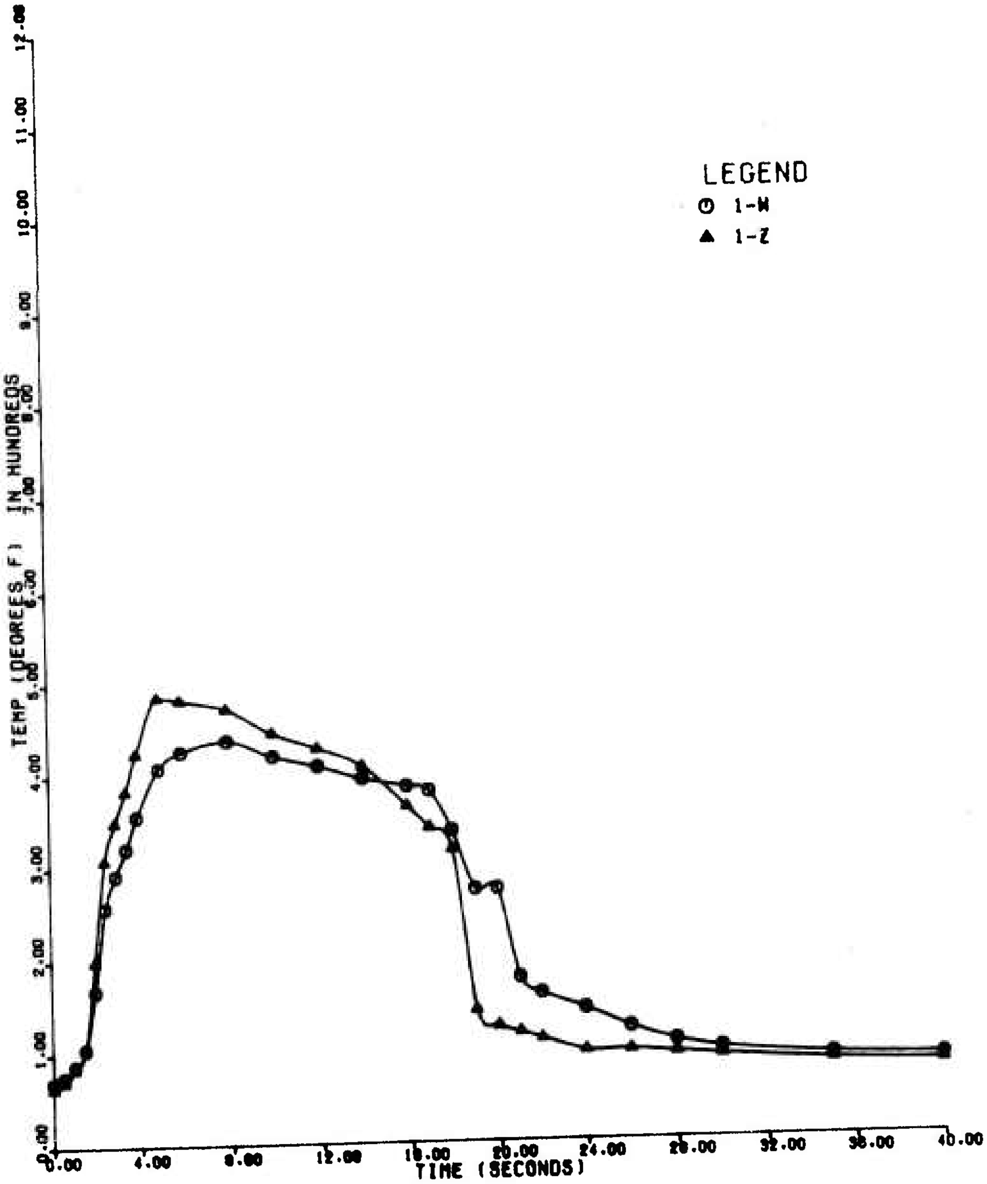


FIGURE D-6

CVA Magazine Test

No. 5

25 October 1973

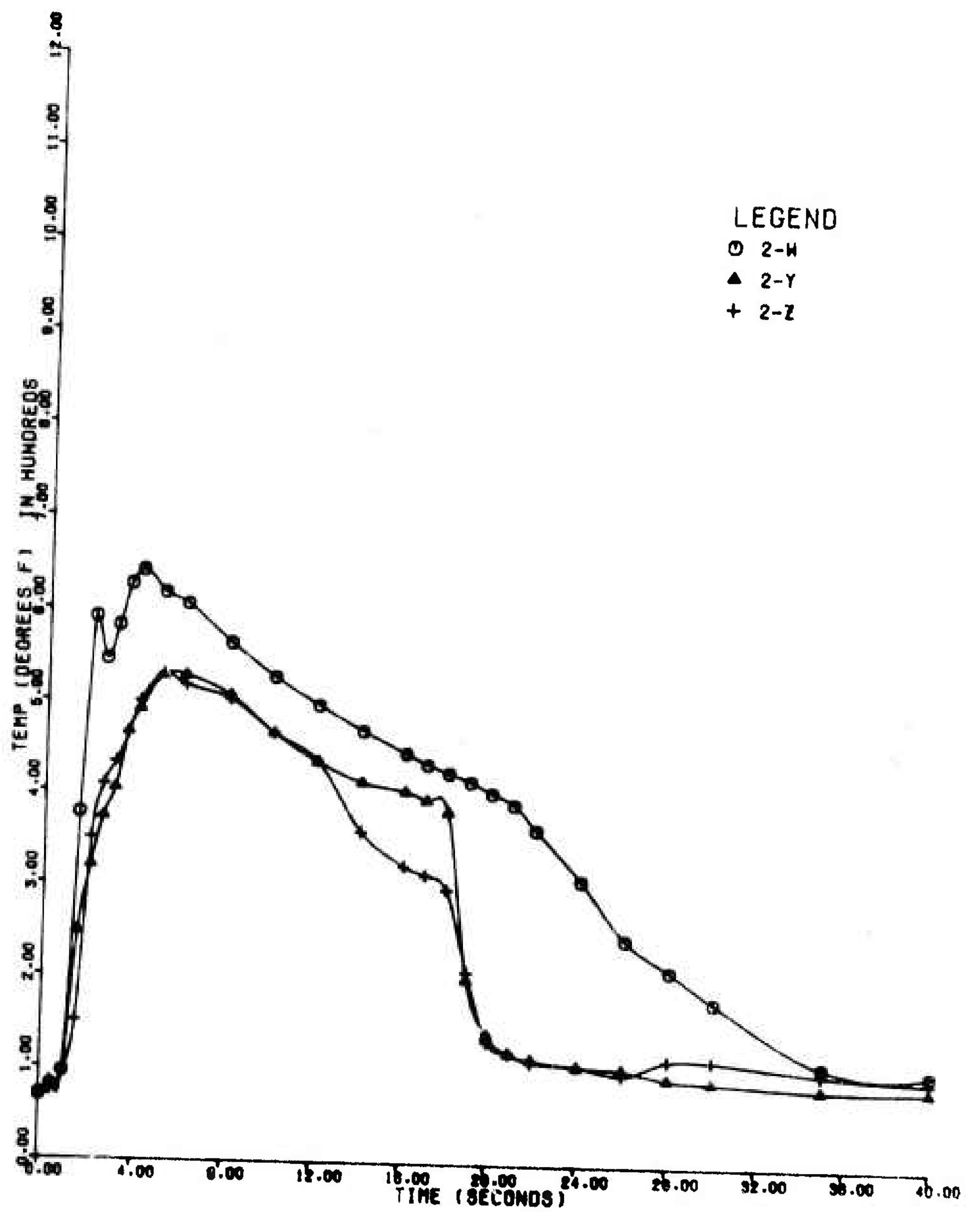


FIGURE D-7

No. 5

CVA Magazine Test

25 October 1973

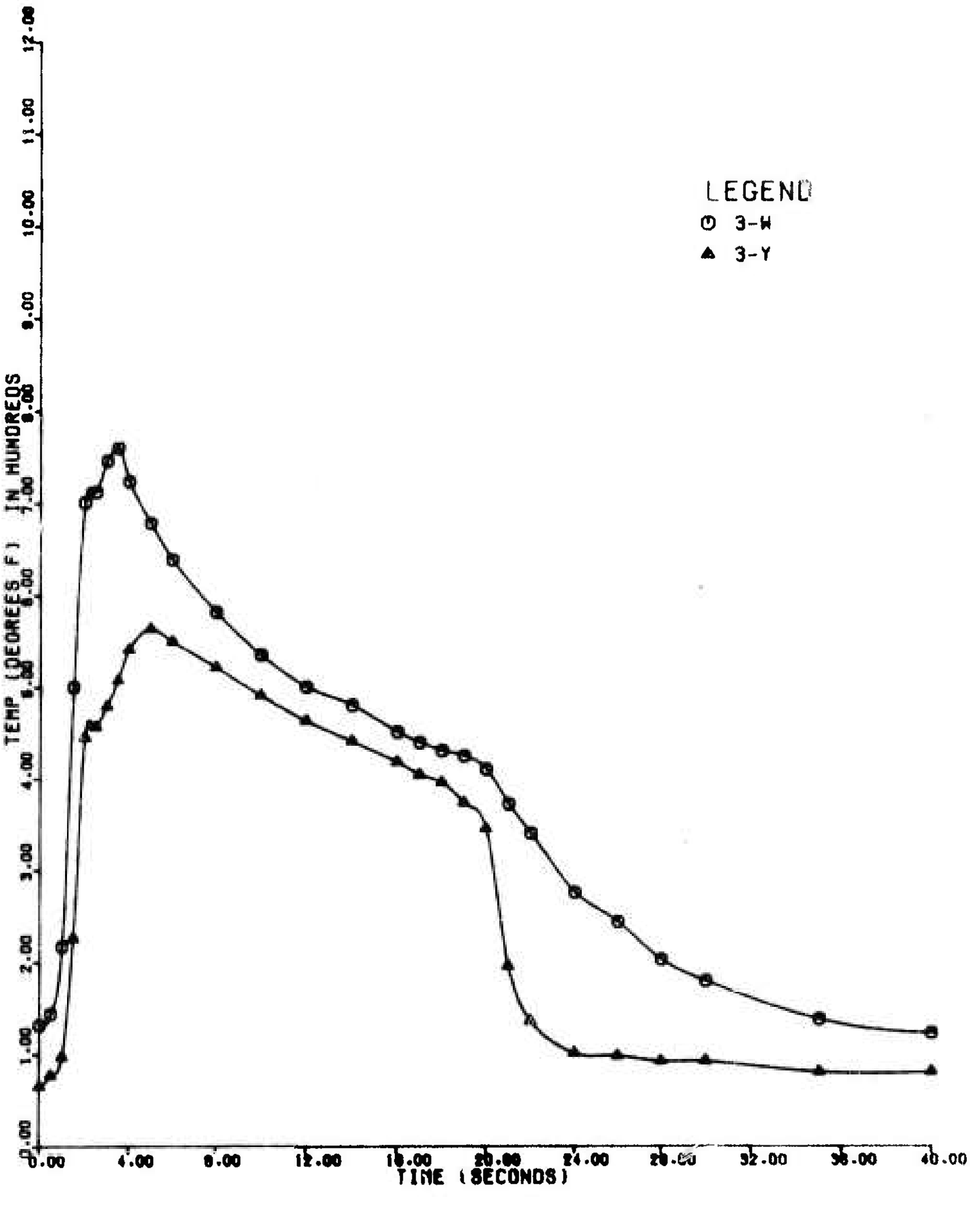


FIGURE D-8

CVA Magazine Test

No. 5 25 October 1973

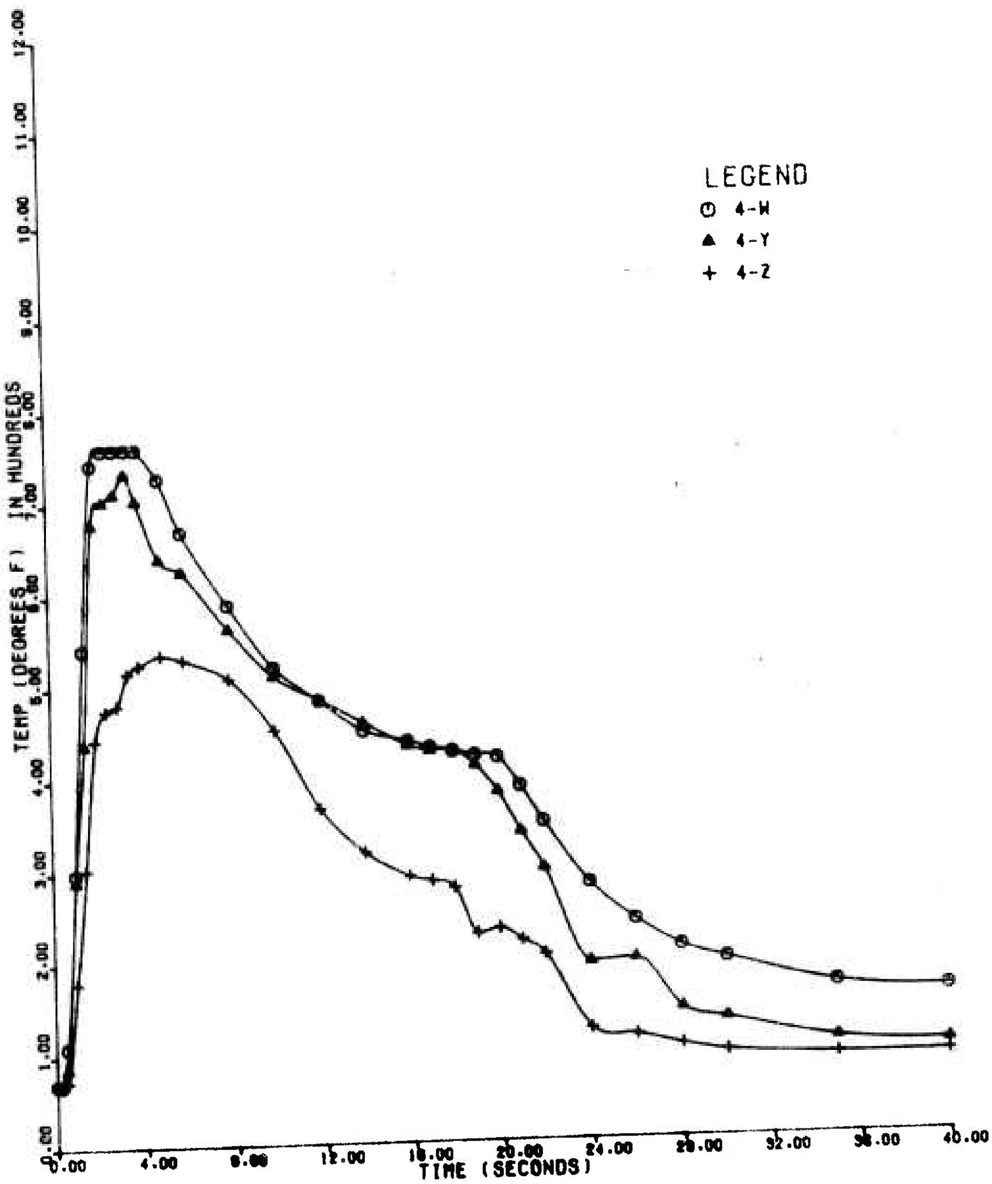


FIGURE D-9

CVA Magazine Test

No. 5

25 October 1973

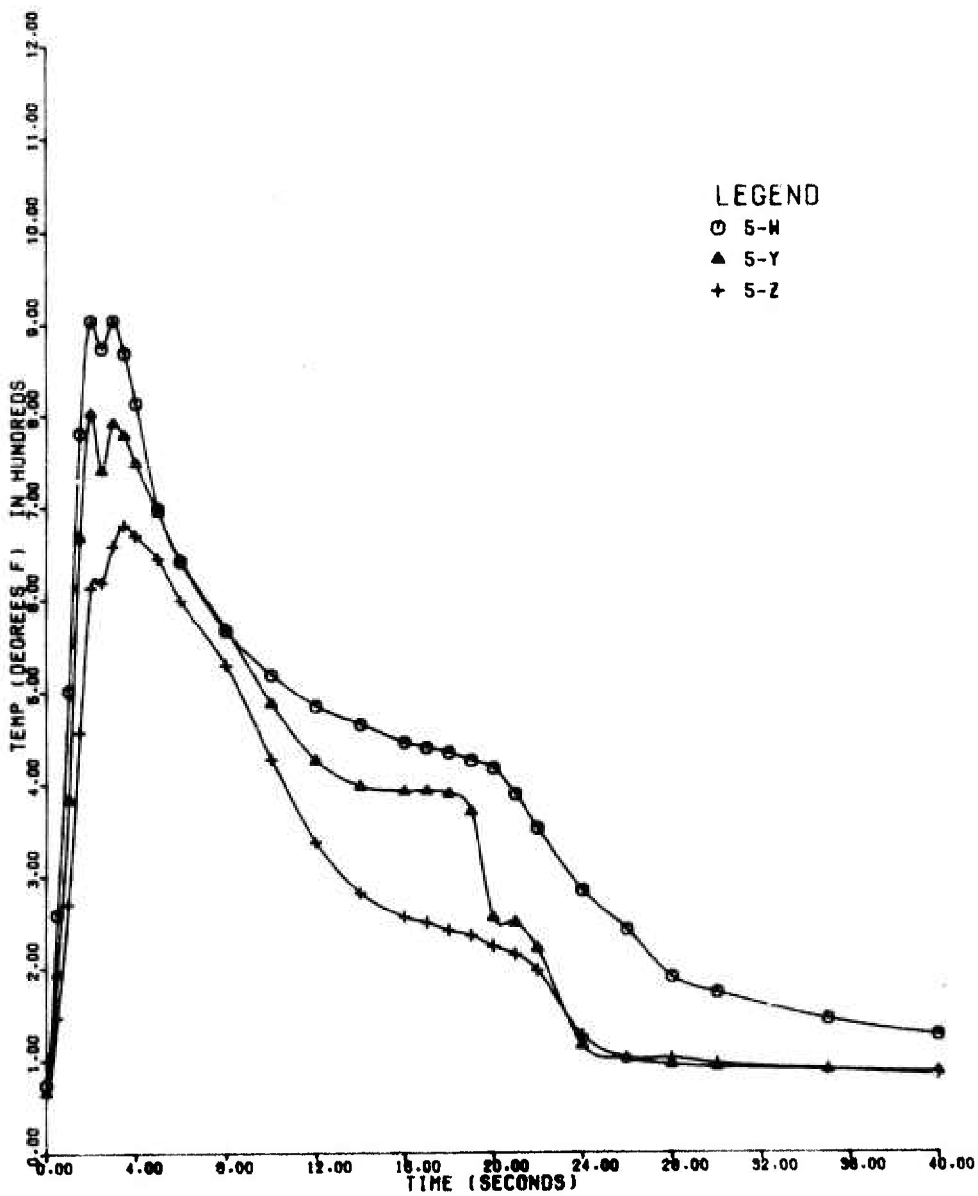


FIGURE D-10

CVA Magazine Test

No. 5 25 October 1973

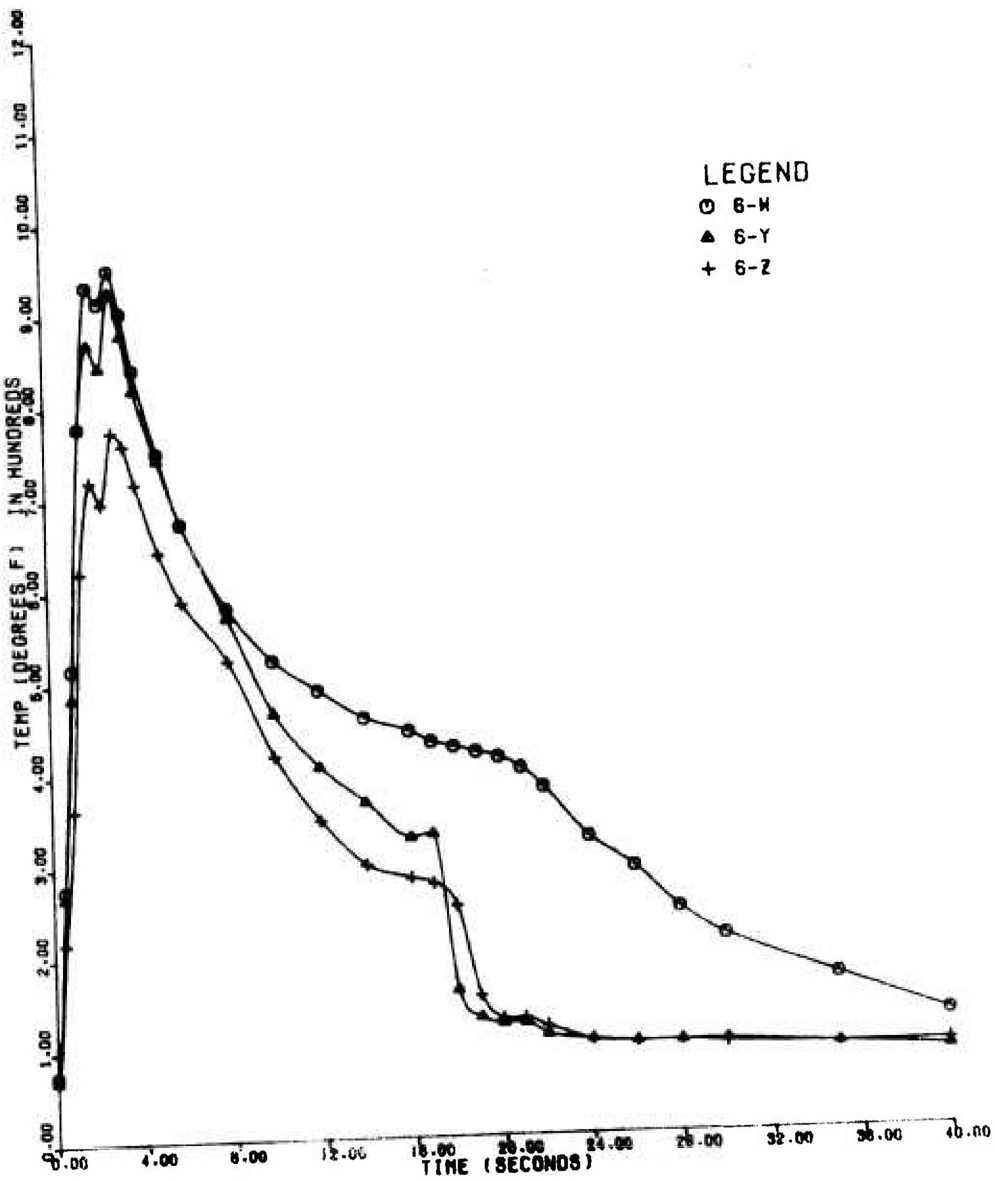


FIGURE D-11

CVA Magazine Test

No. 5

25 October 1973

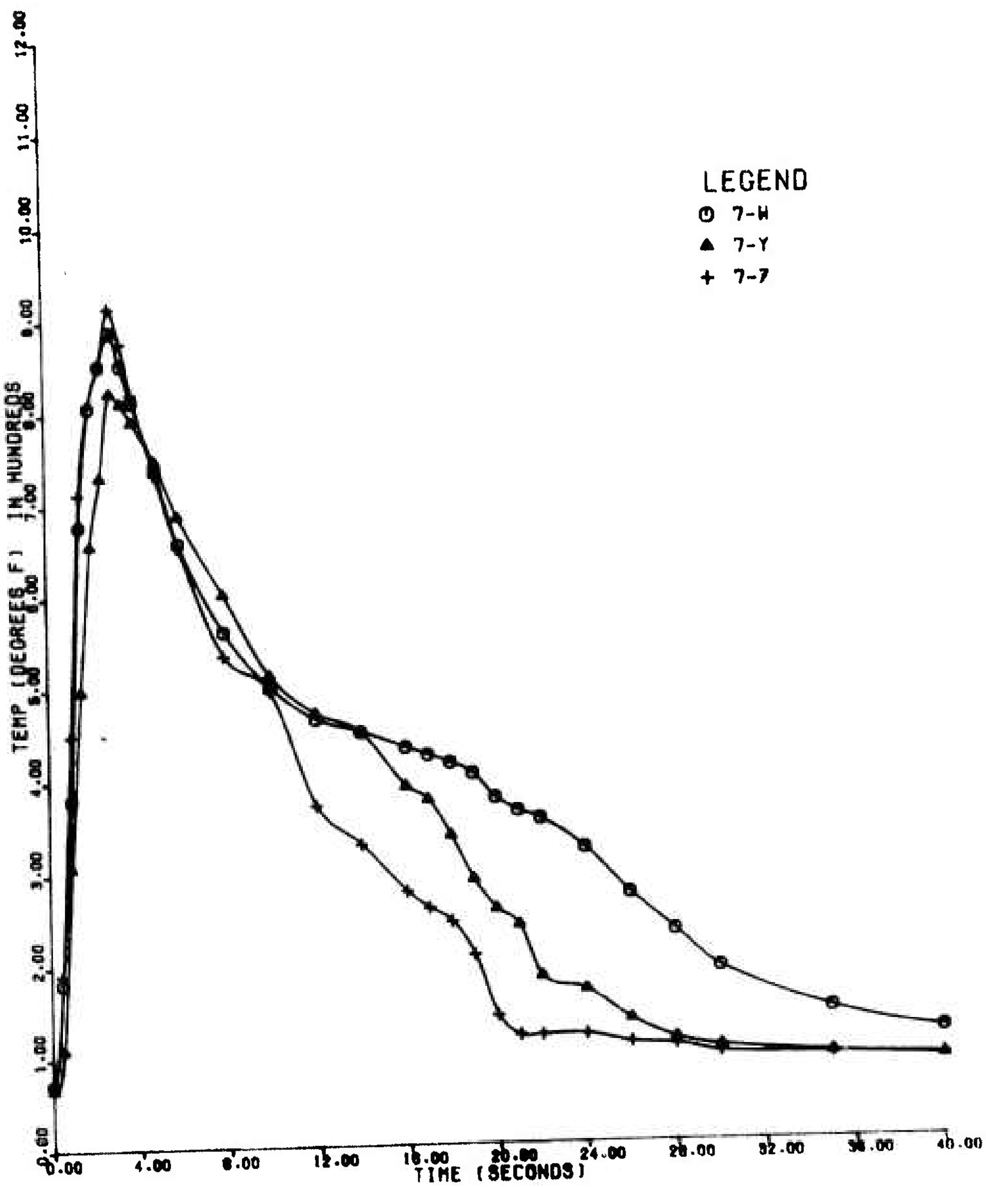


FIGURE D-12

CVA Magazine Test

No. 5

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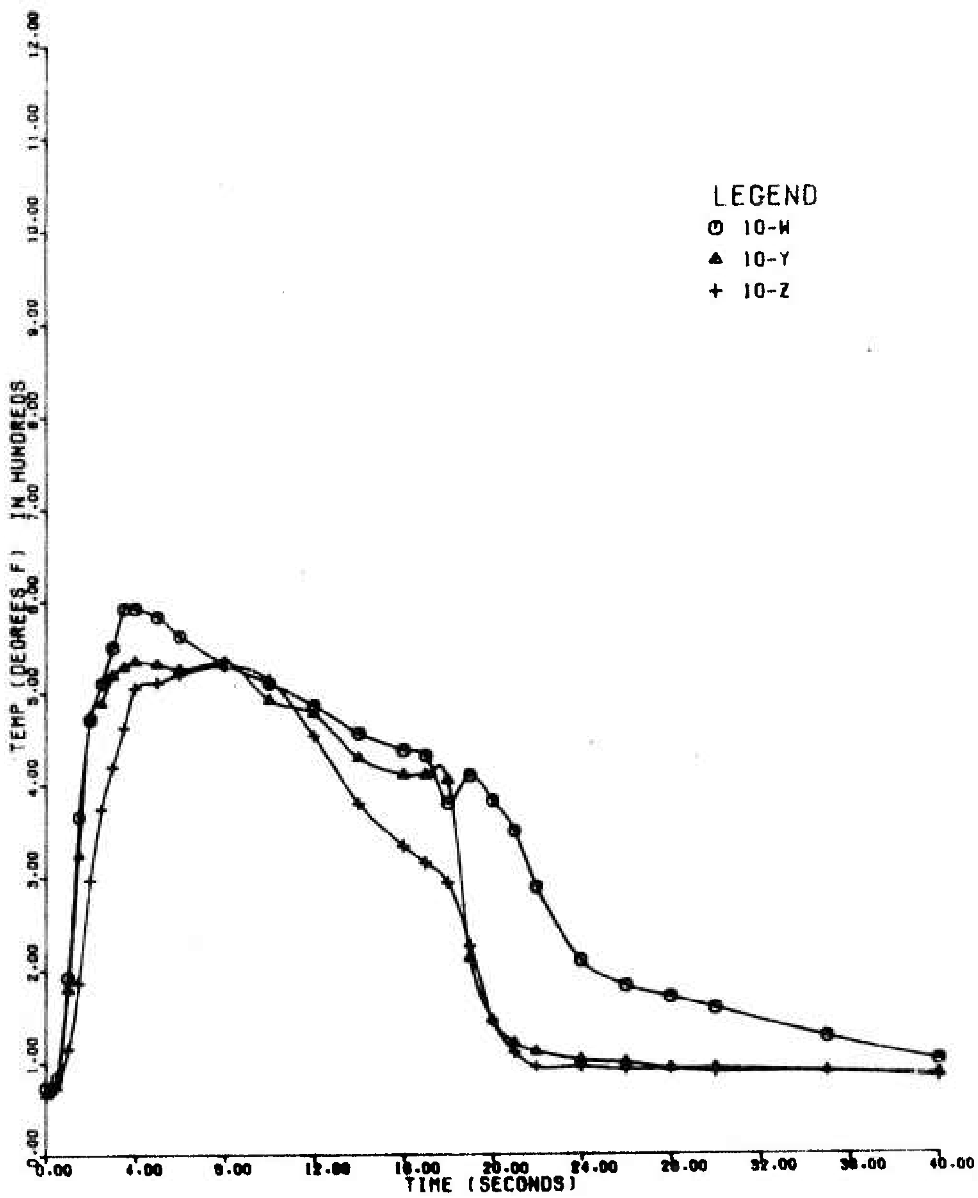

FIGURE D-13

CVA Magazine Test

No. 5 25 October 1973

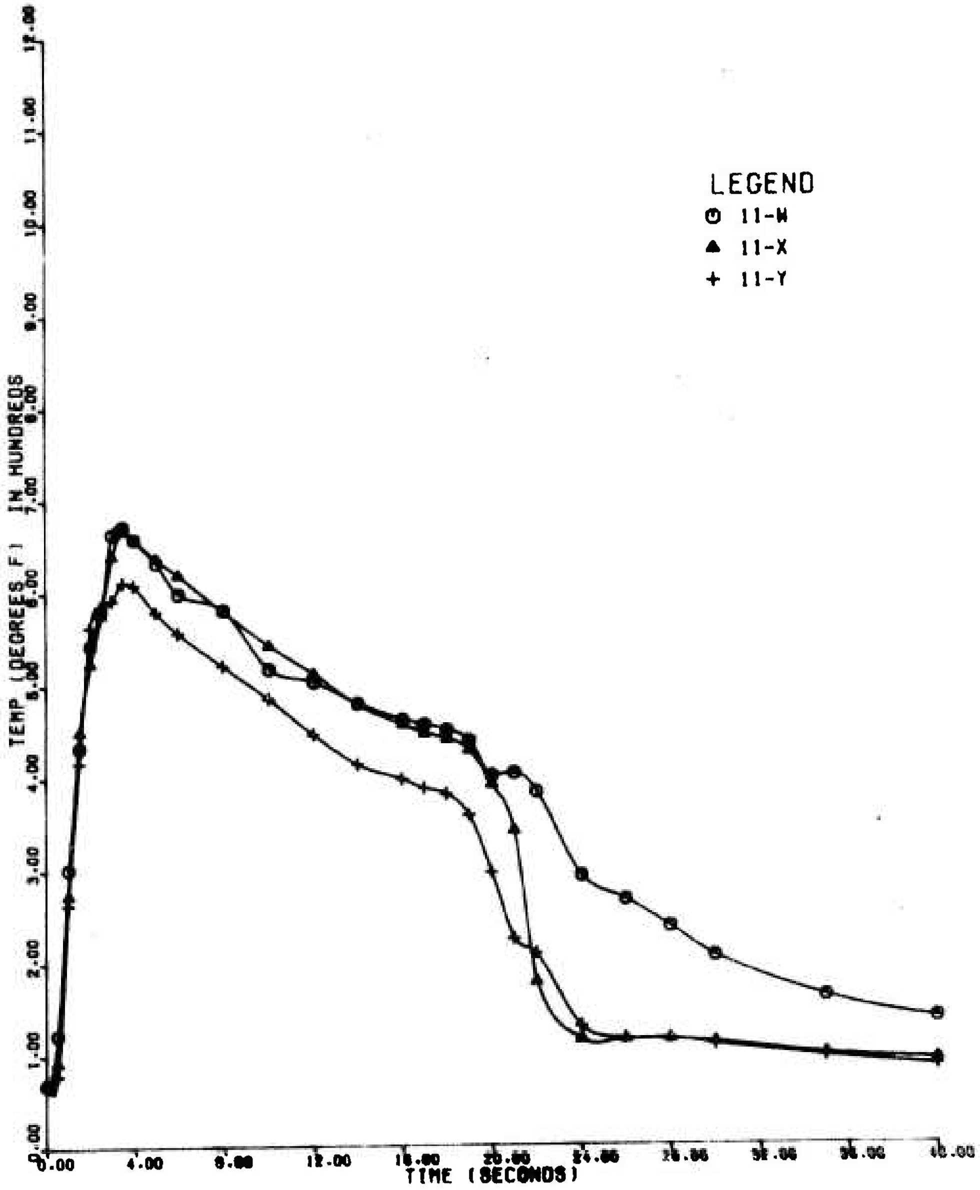

FIGURE D-14

CVA Magazine Test

No. 5

25 October 1973

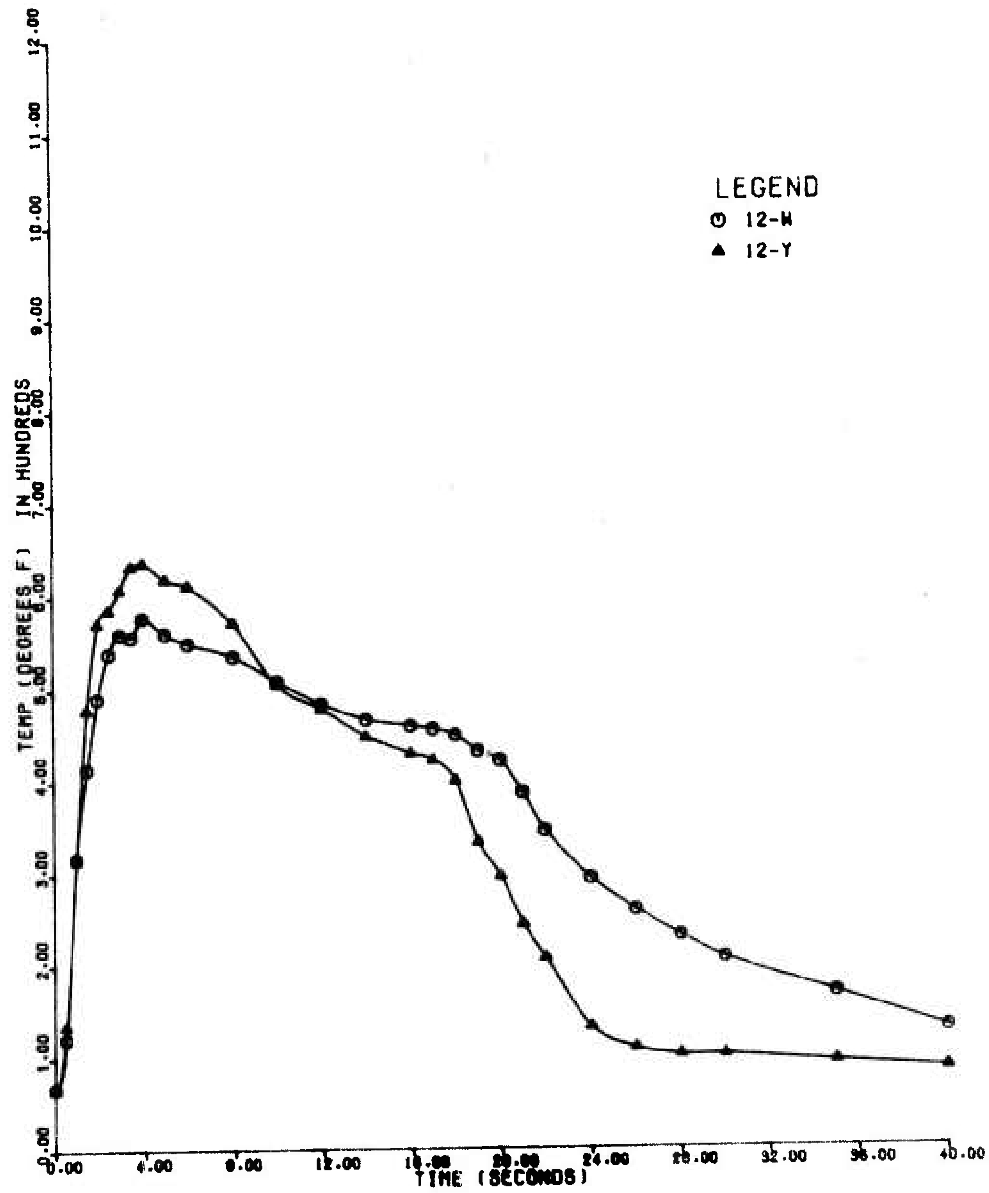

FIGURE D-15

CVA Magazine Test

No. 5

25 October 1973

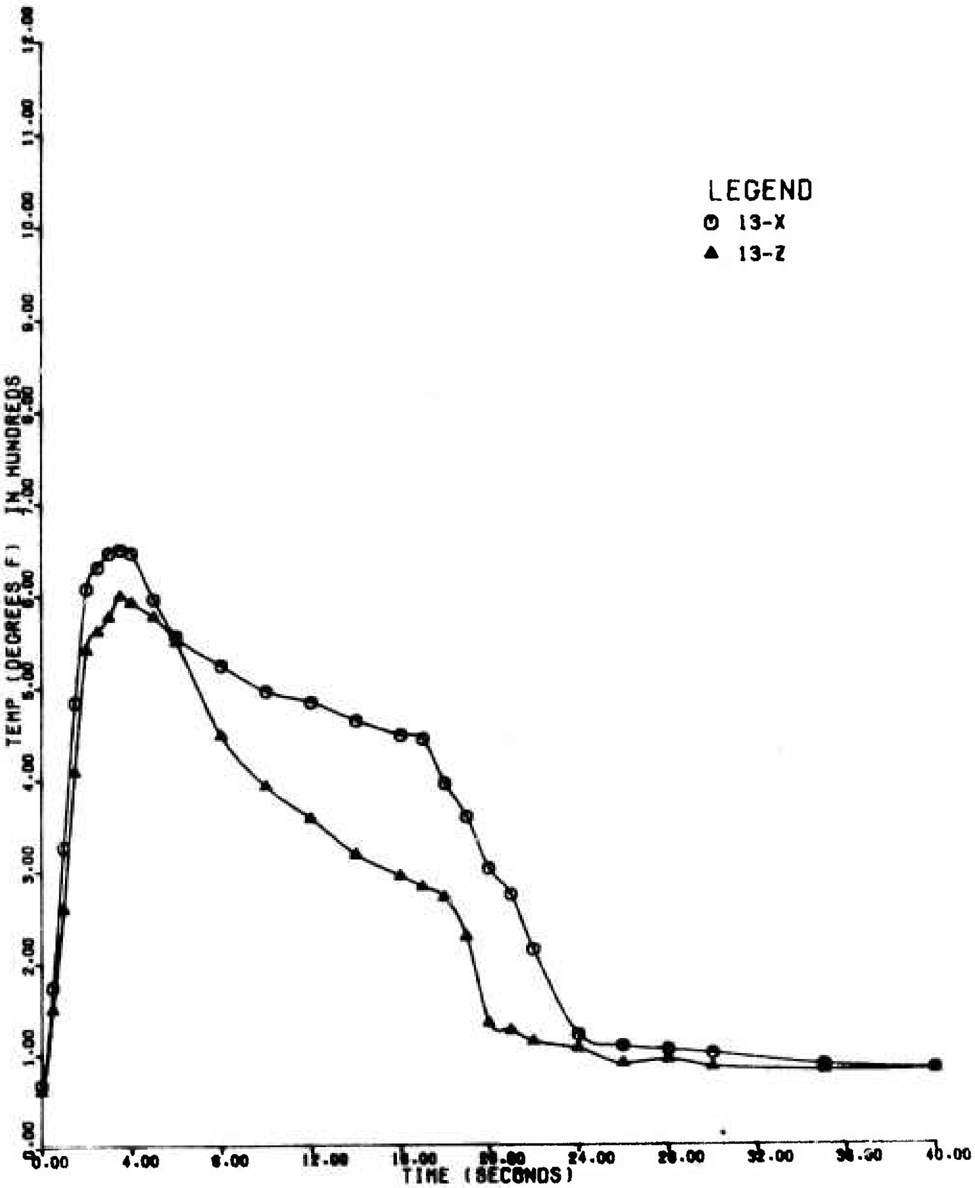

FIGURE D-16

CVA Magazine Test

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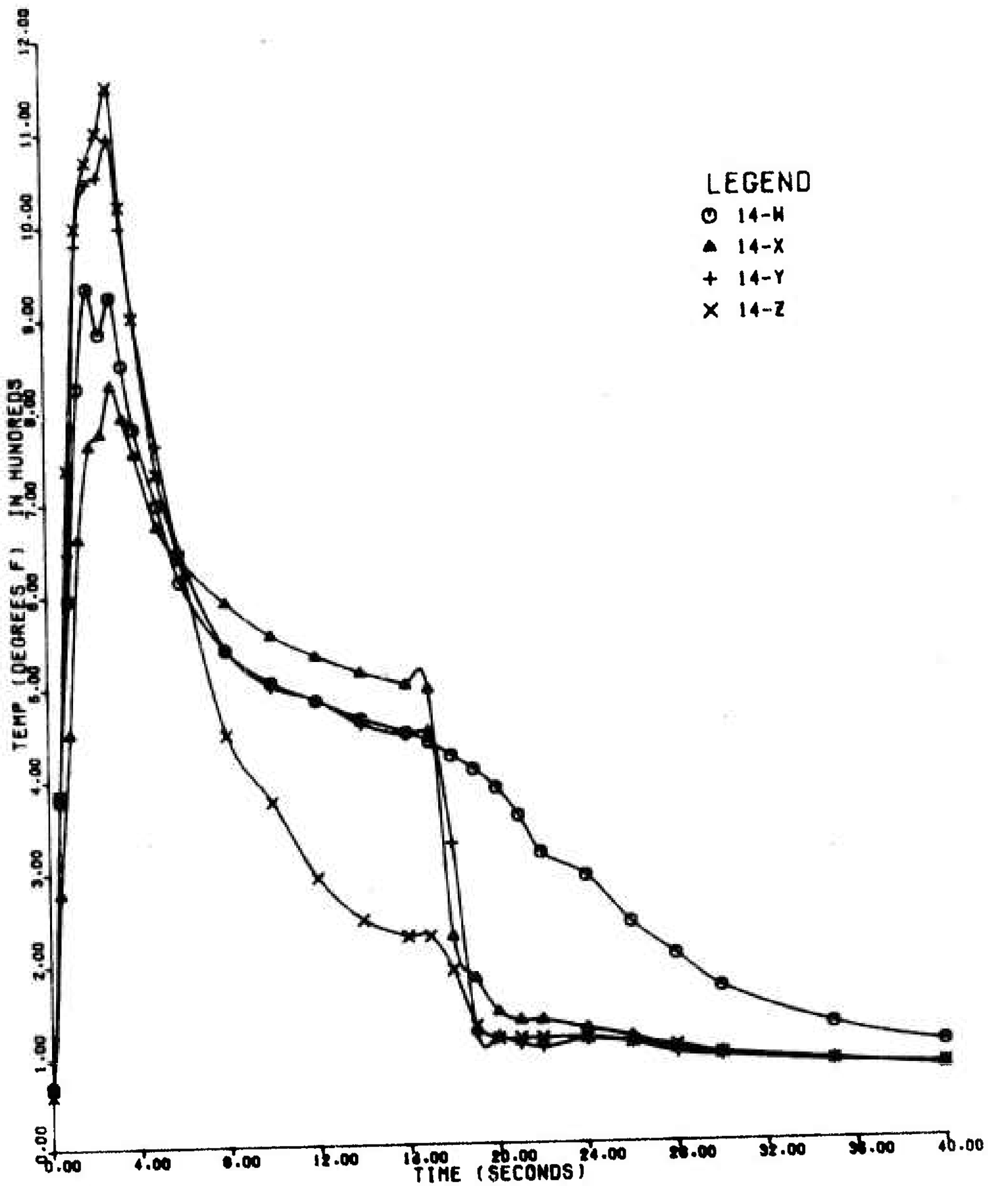

FIGURE D-17

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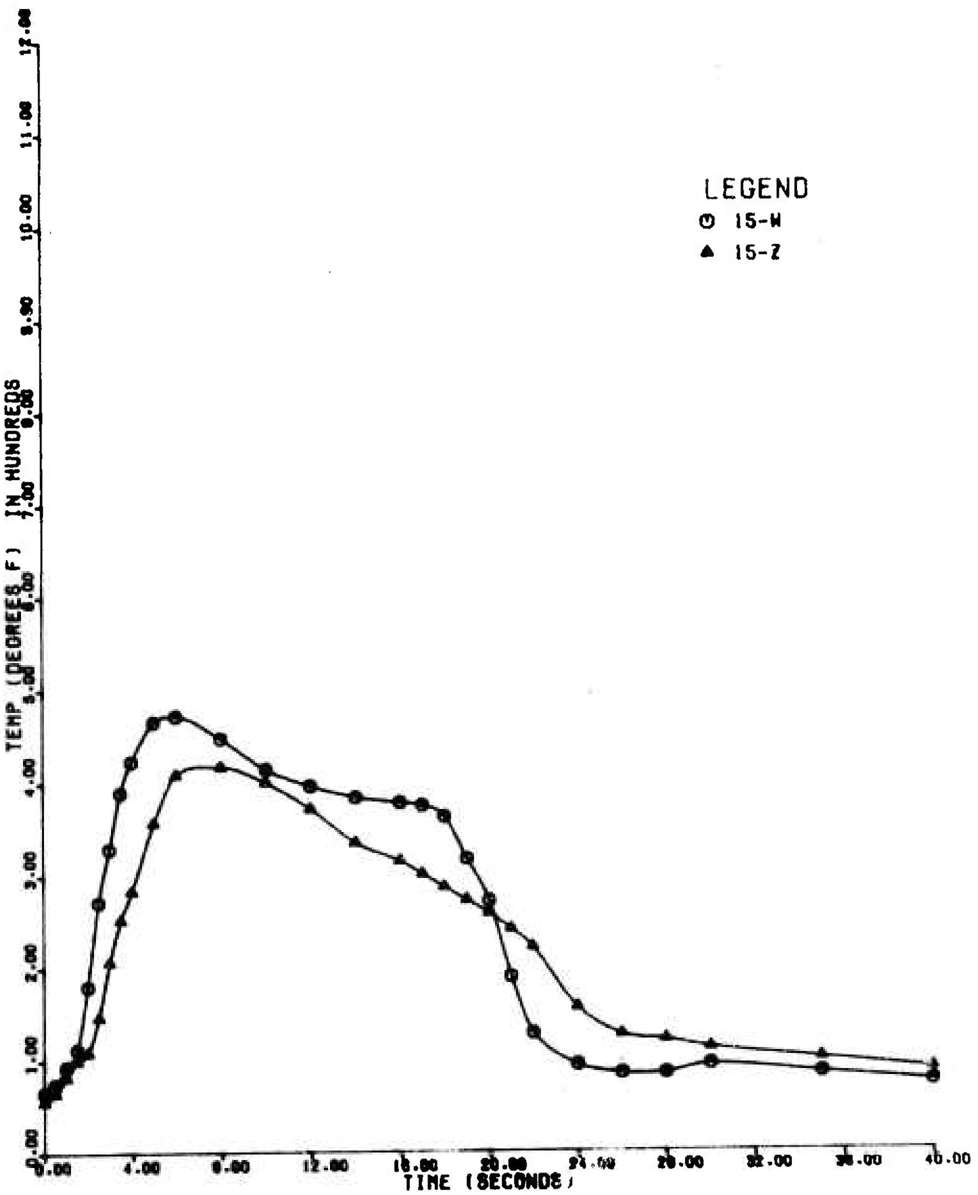

FIGURE D-18

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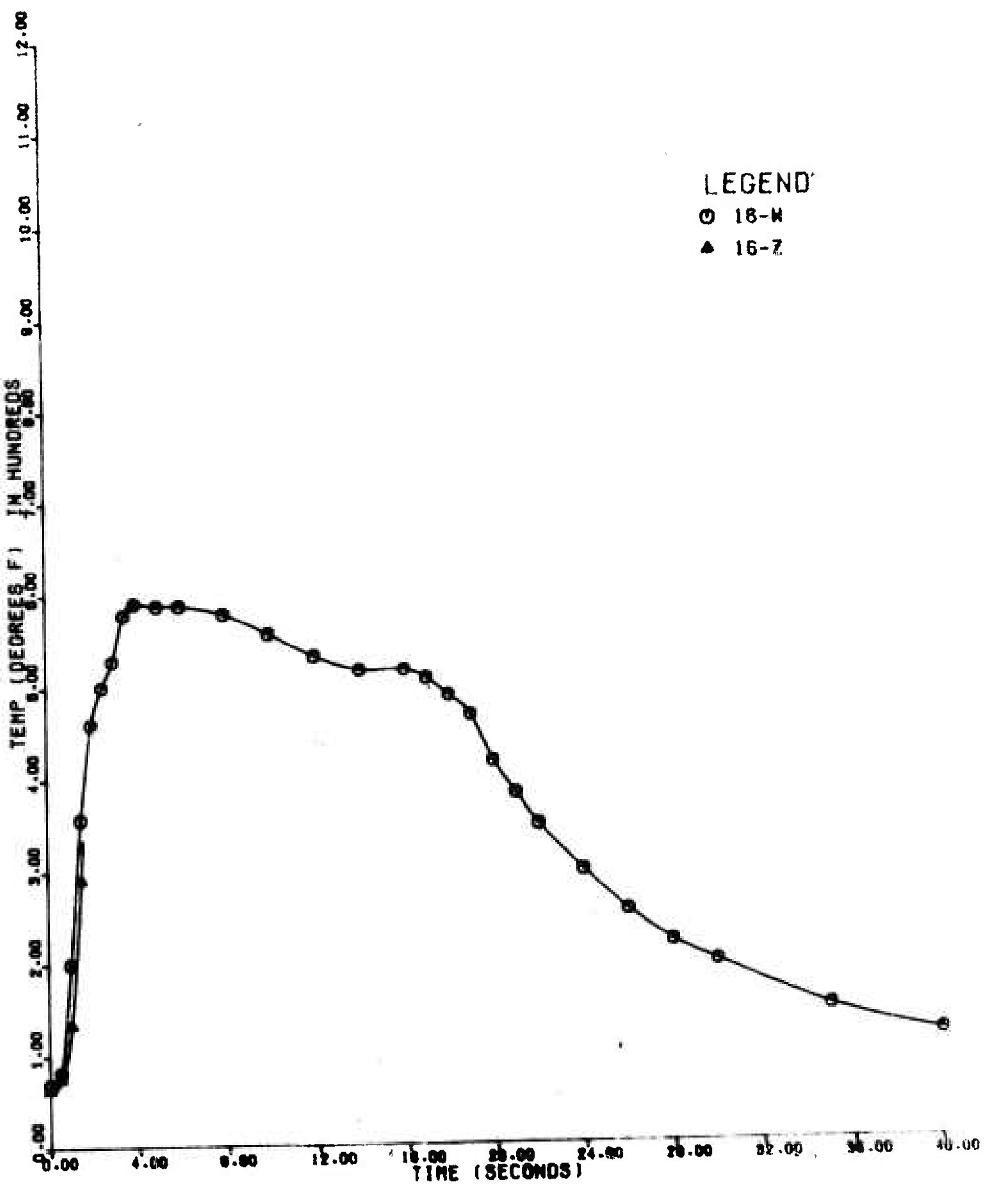

FIGURE D-19

CVA Magazine Test

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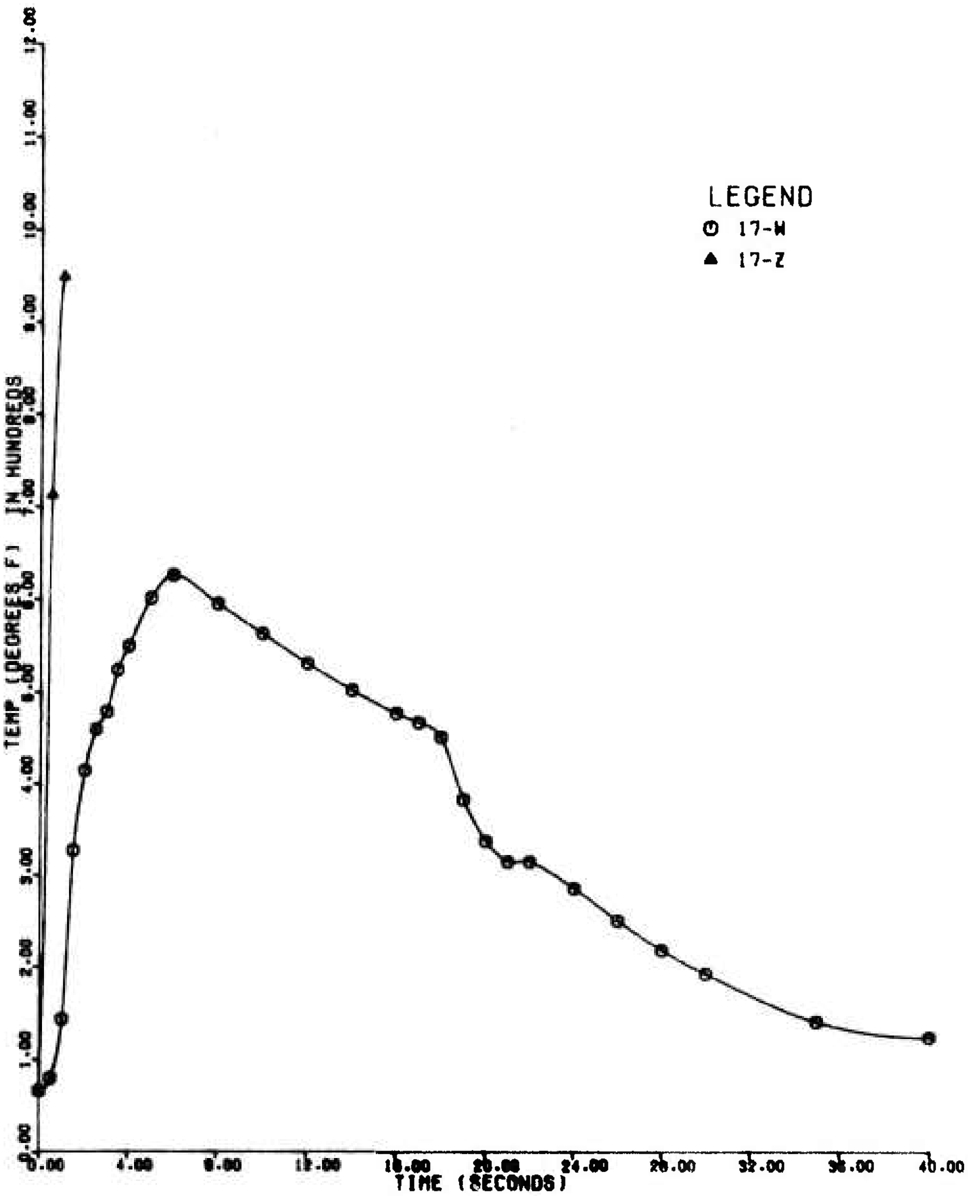

FIGURE D-20

CVA Magazine Test

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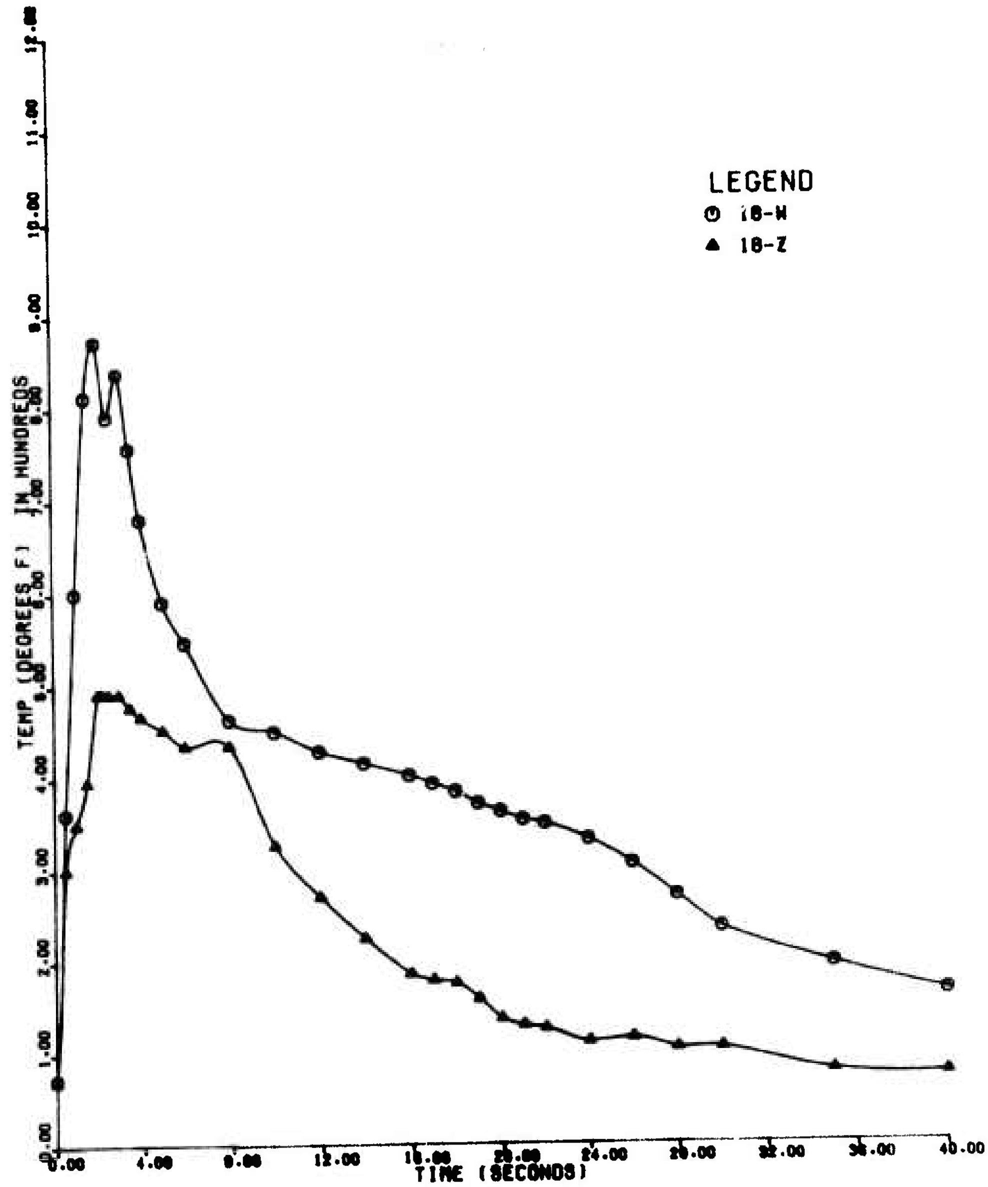

FIGURE D-21

CVA Magazine Test

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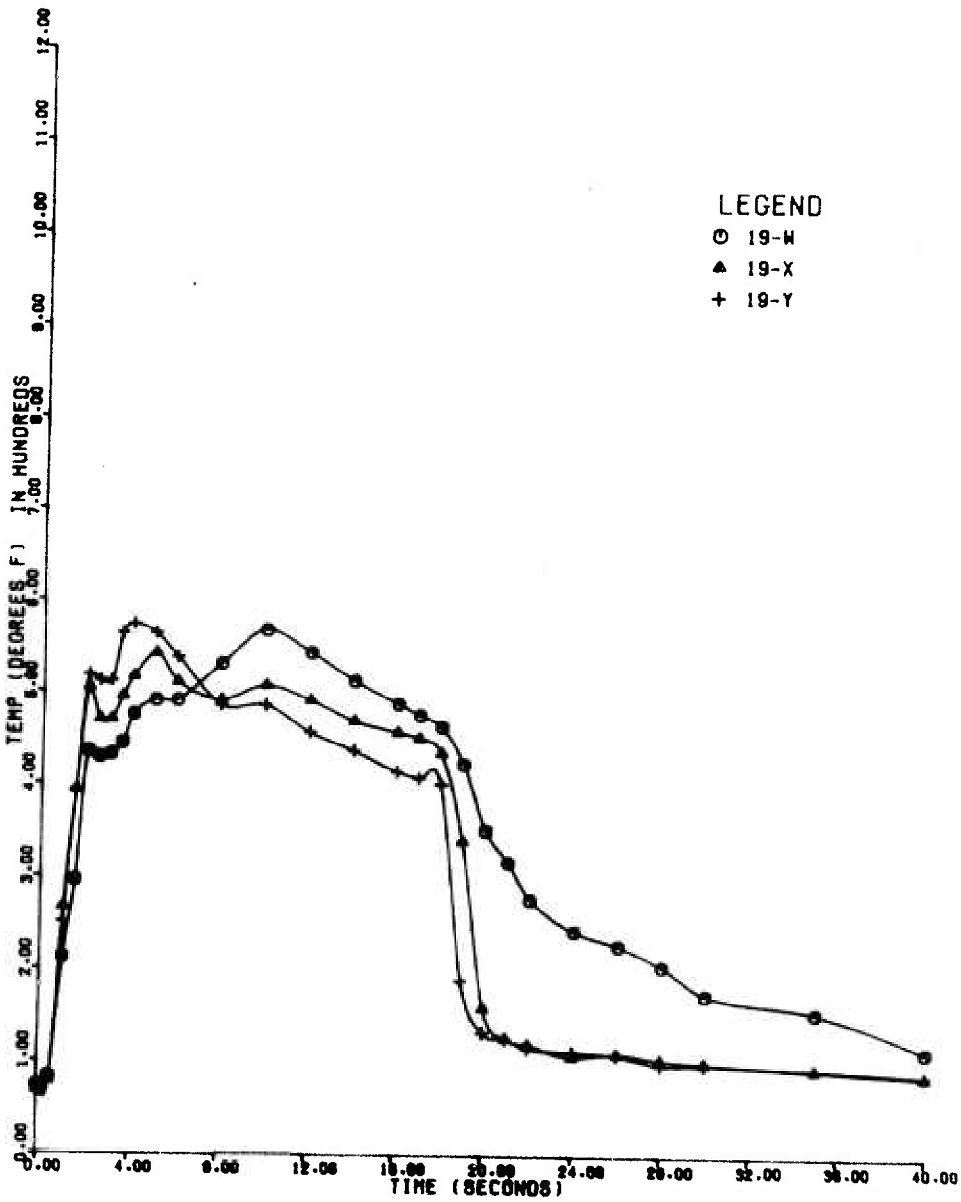

FIGURE D-22

CVA Magazine Test

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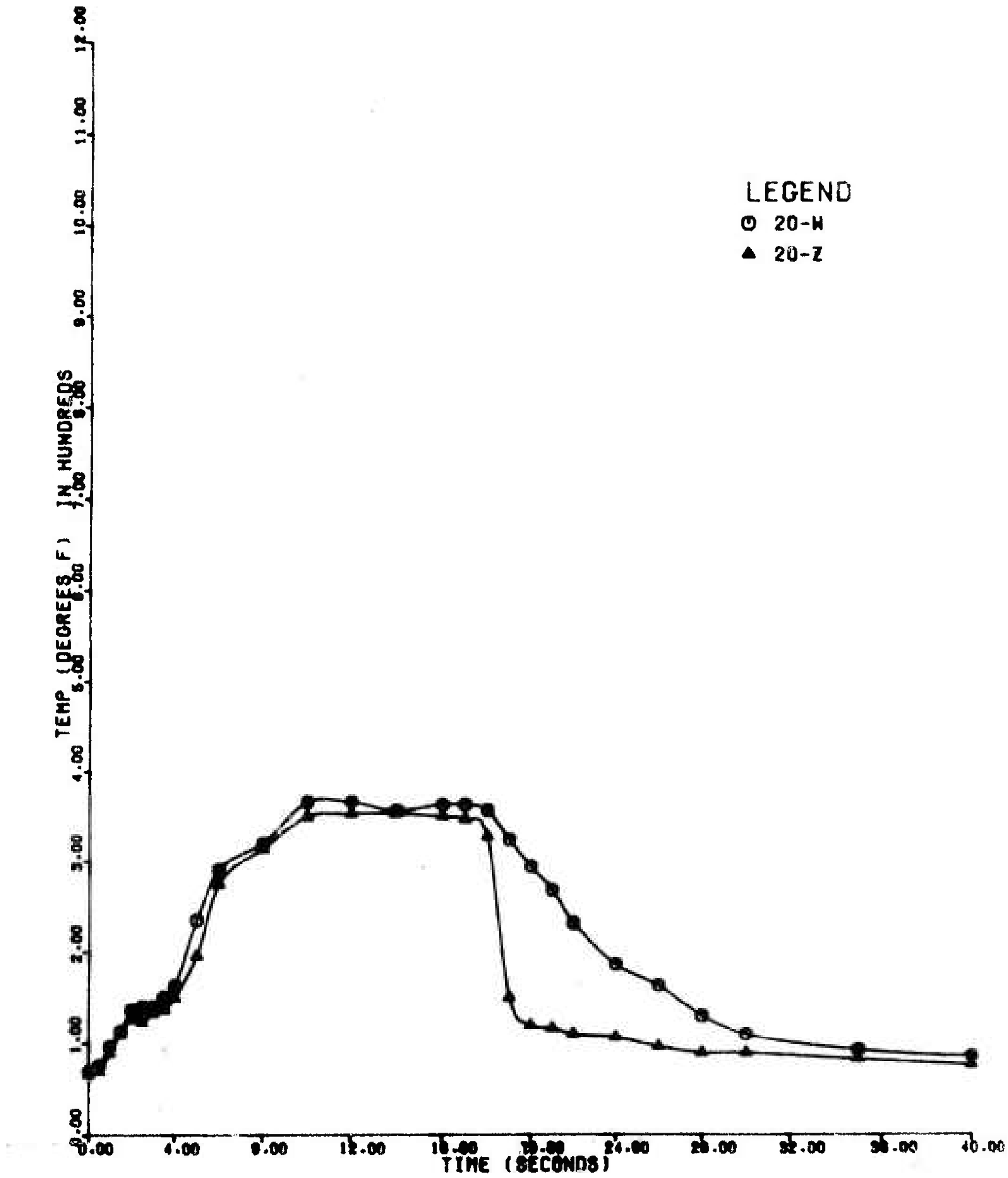

FIGURE D-23

CVA Magazine Test

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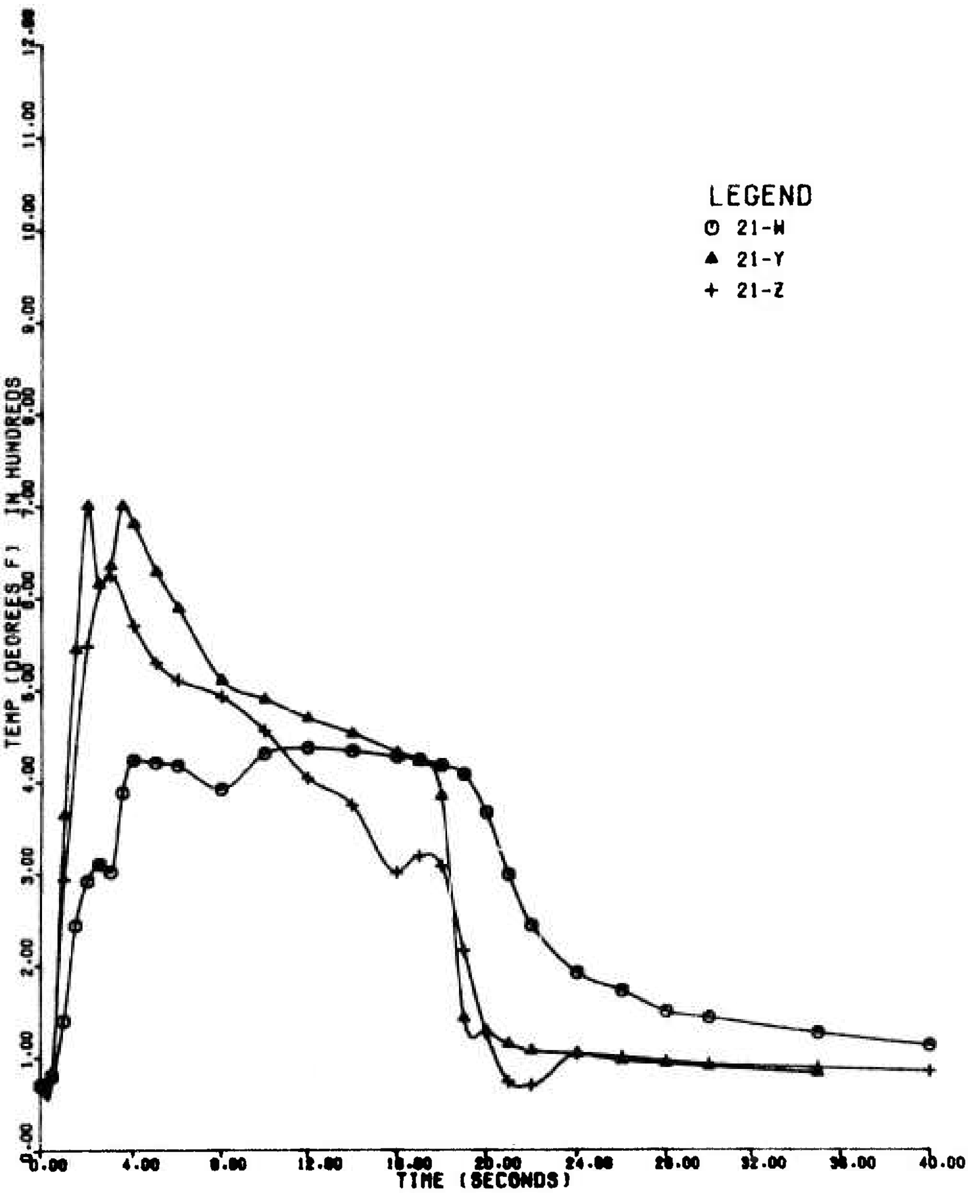

FIGURE D-24

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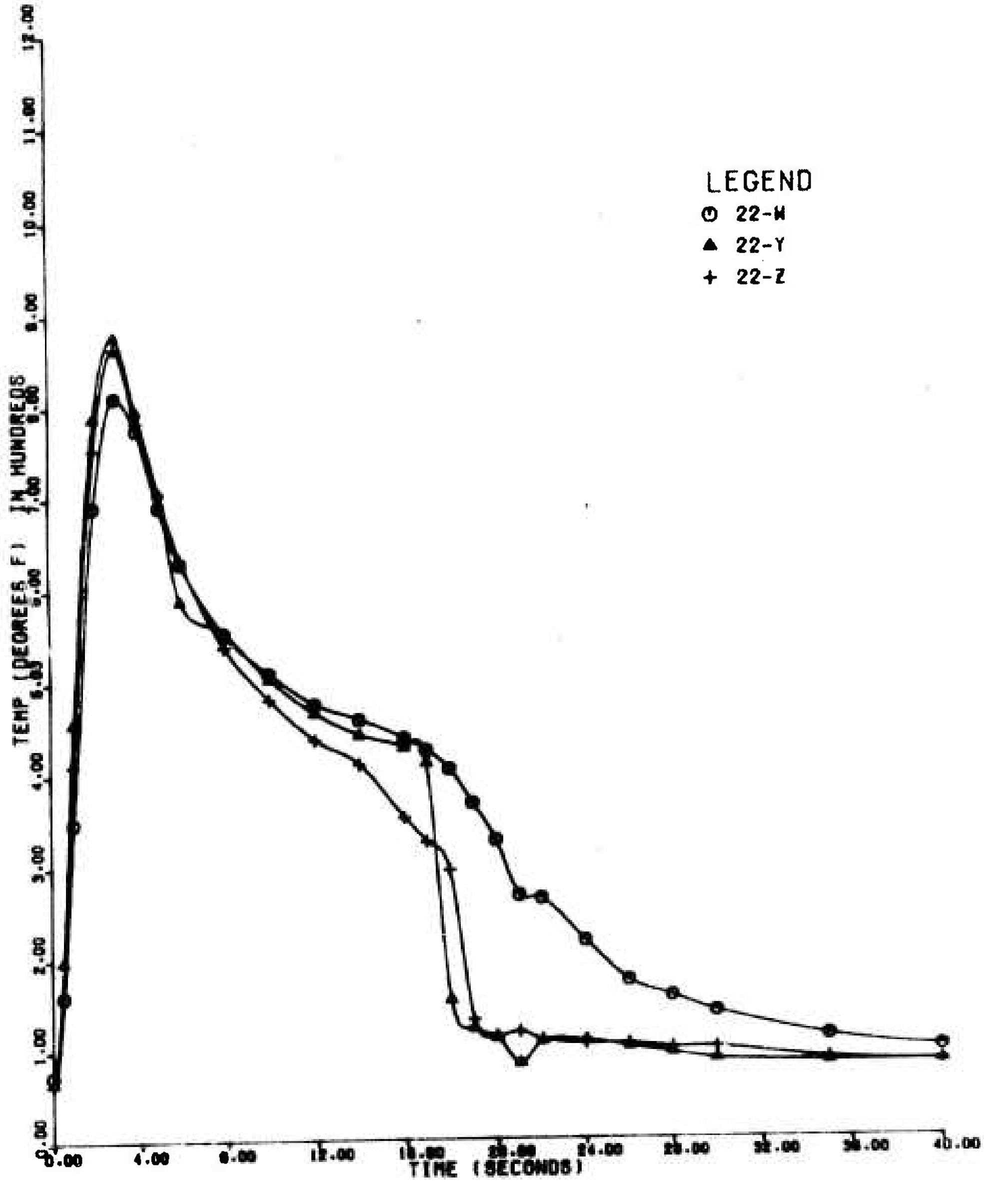

FIGURE D-25

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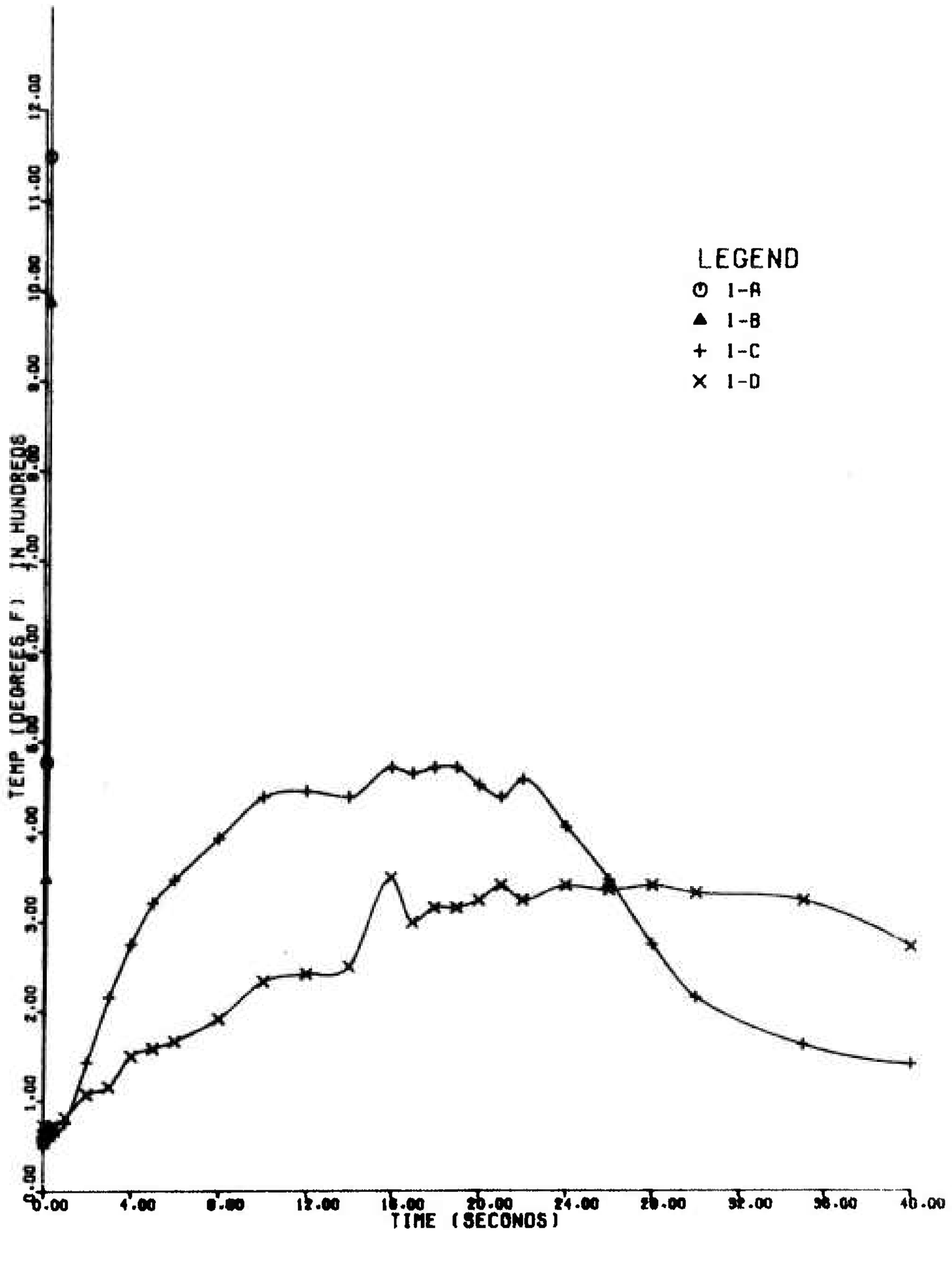

FIGURE D-26

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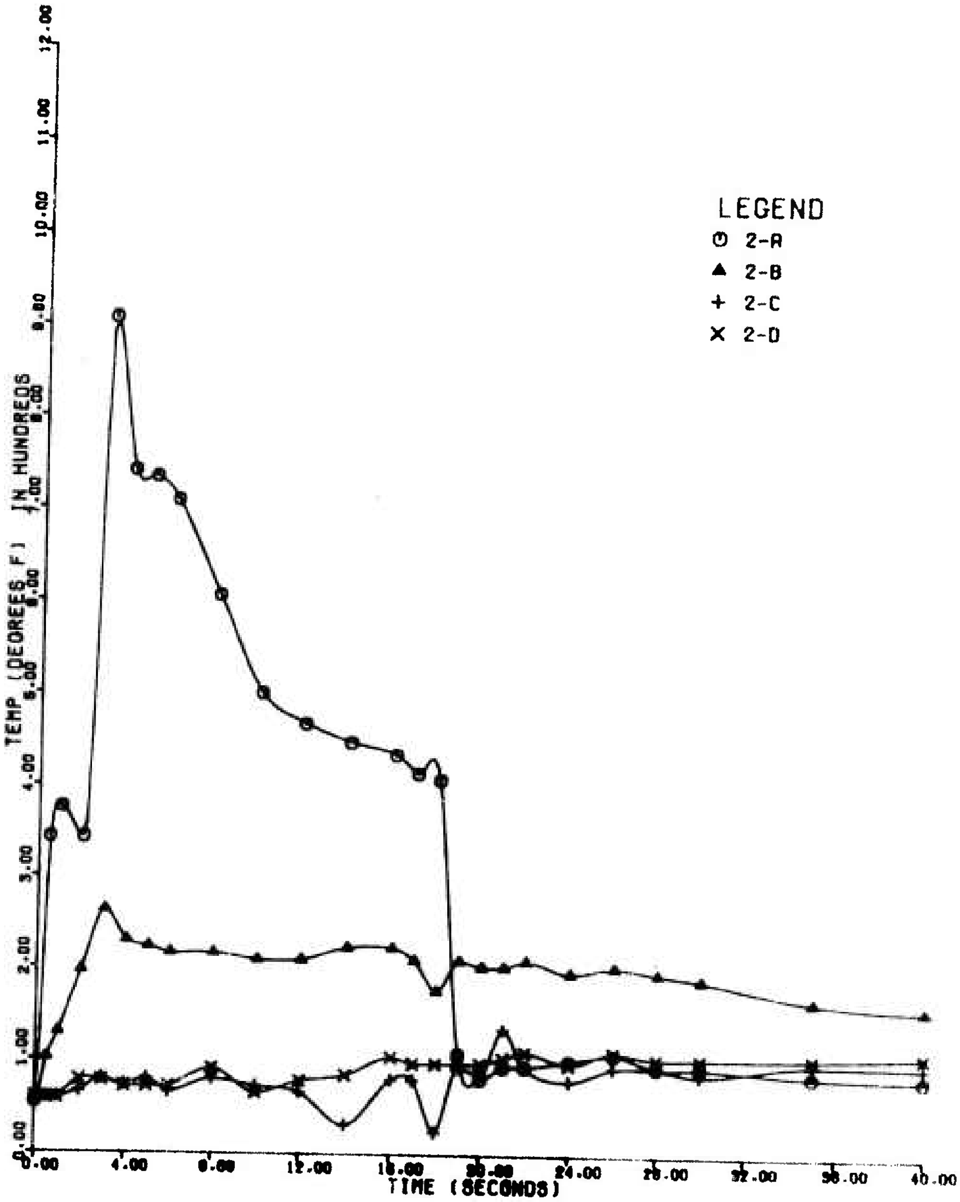

FIGURE D-27

No. 5

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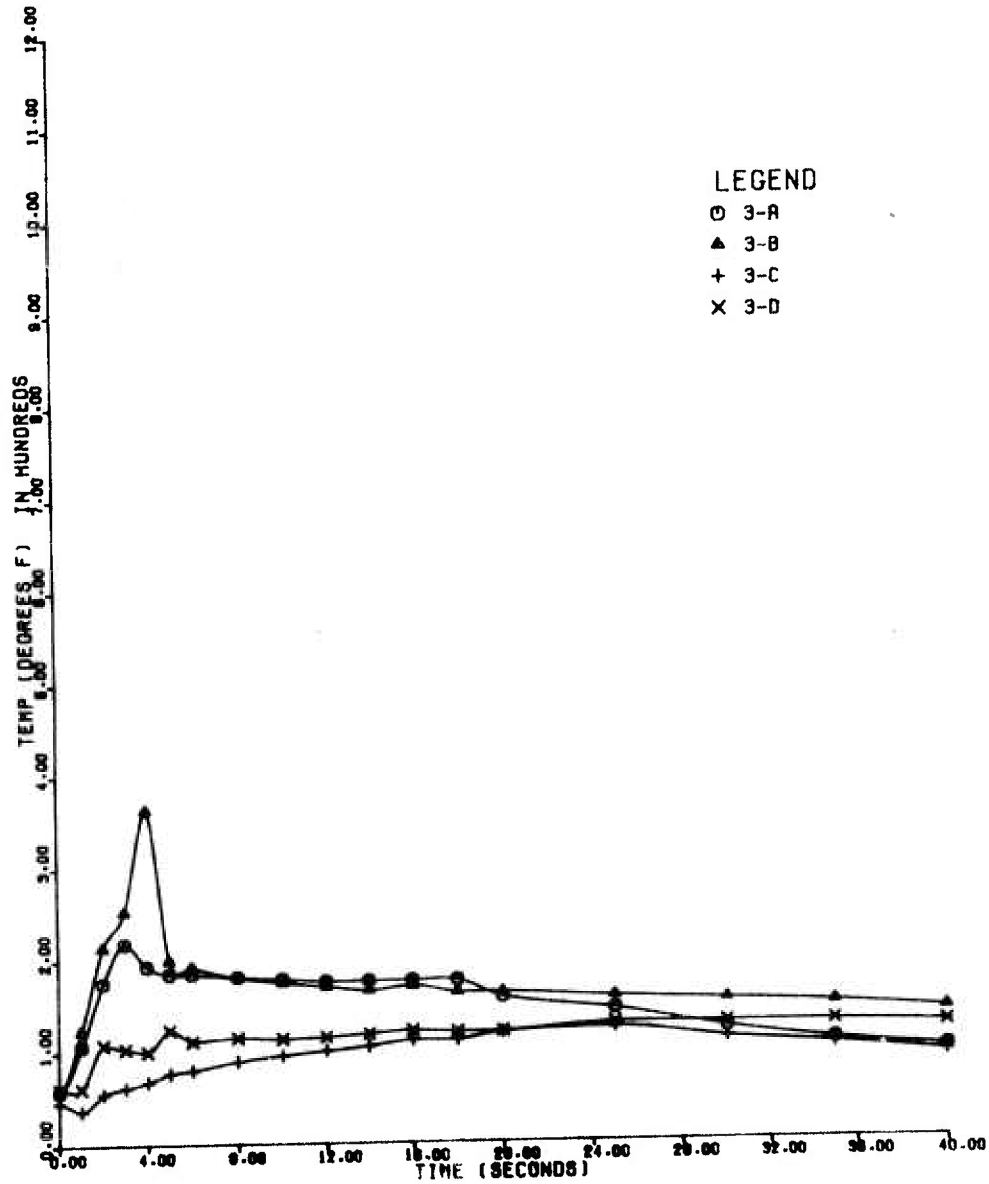

FIGURE D-28

CVA Magazine Test

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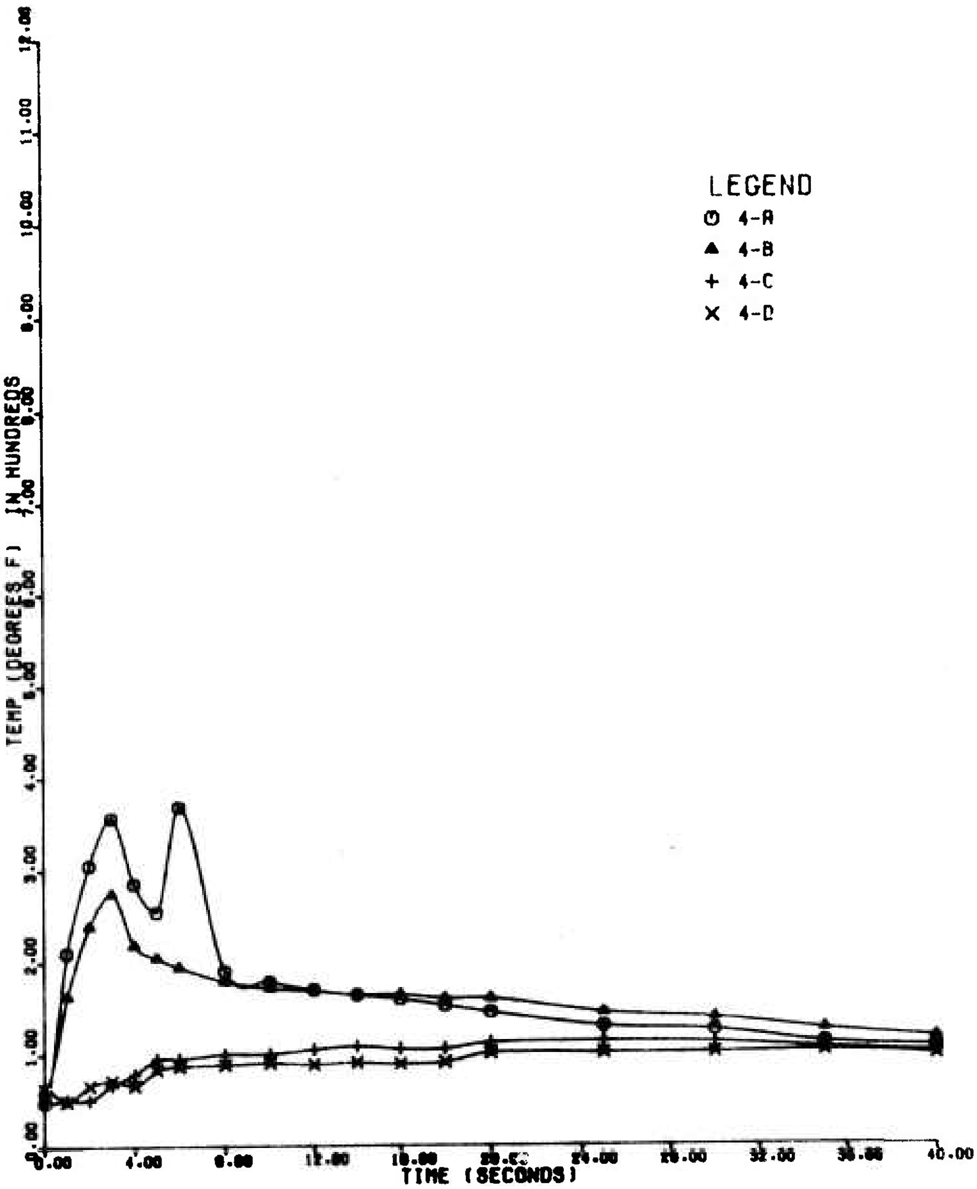

FIGURE D-29

CVA Magazine Test

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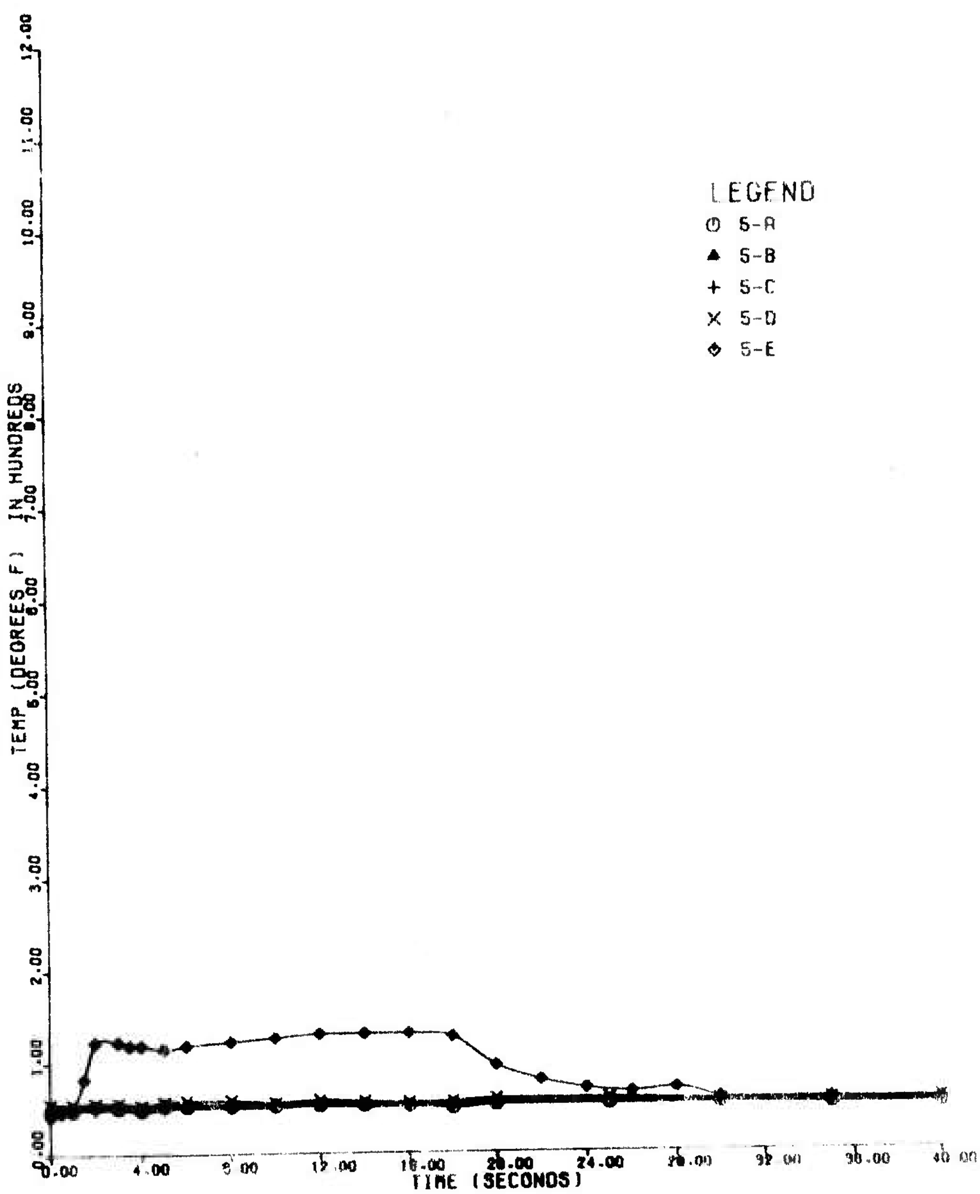

FIGURE D-30

CVA Magazine Test

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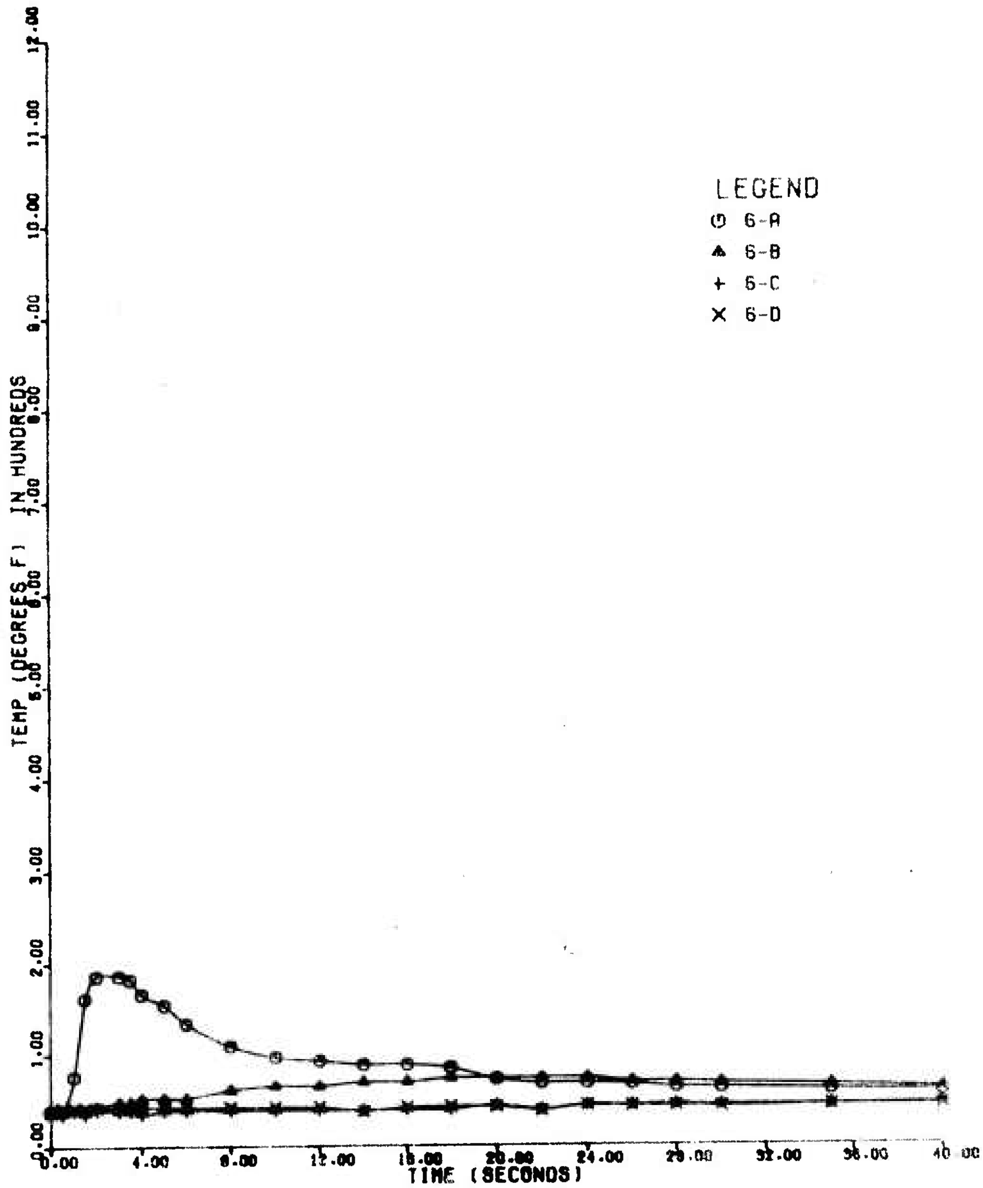

FIGURE D-31

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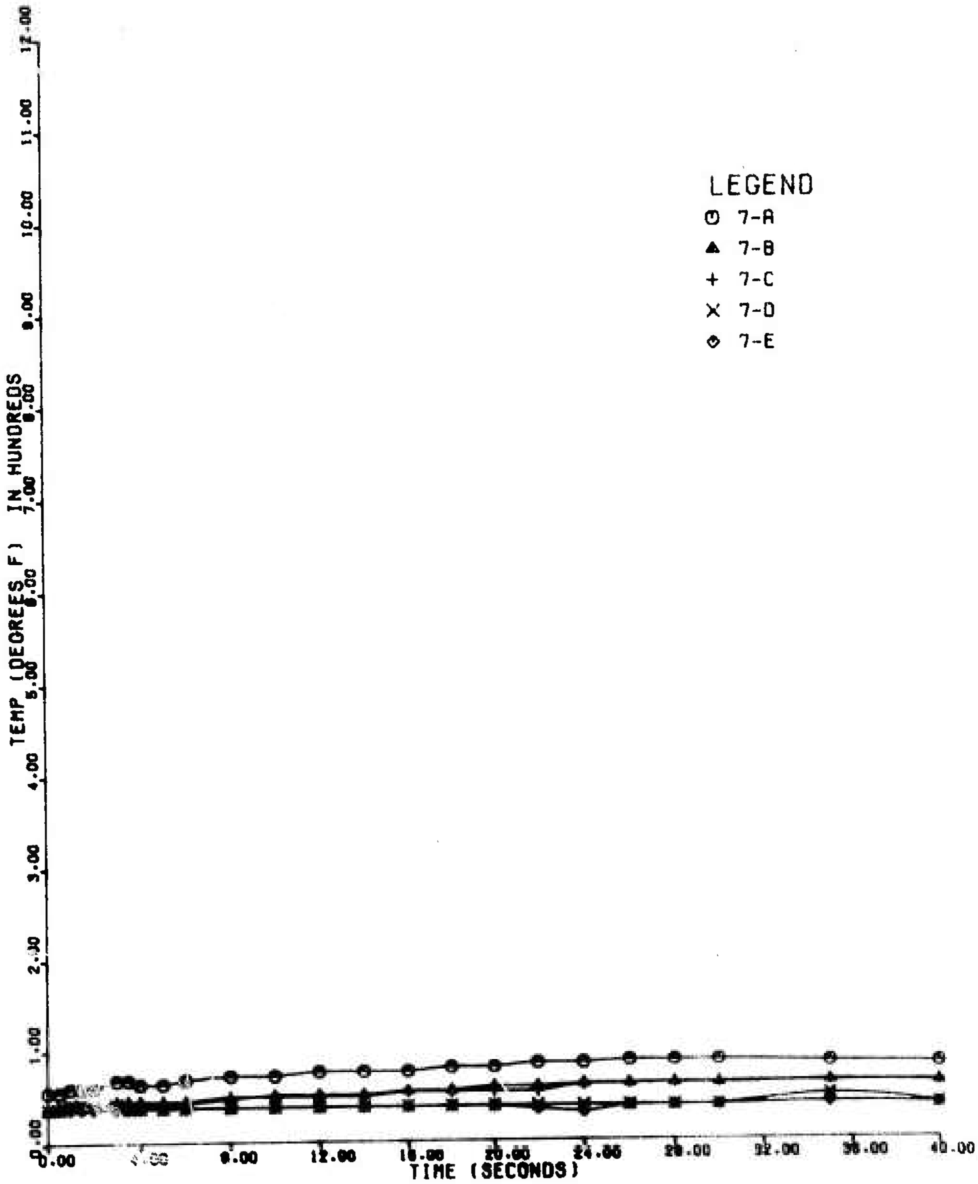

FIGURE D-32

CVA Magazine Test

No. 5

25 October 1973

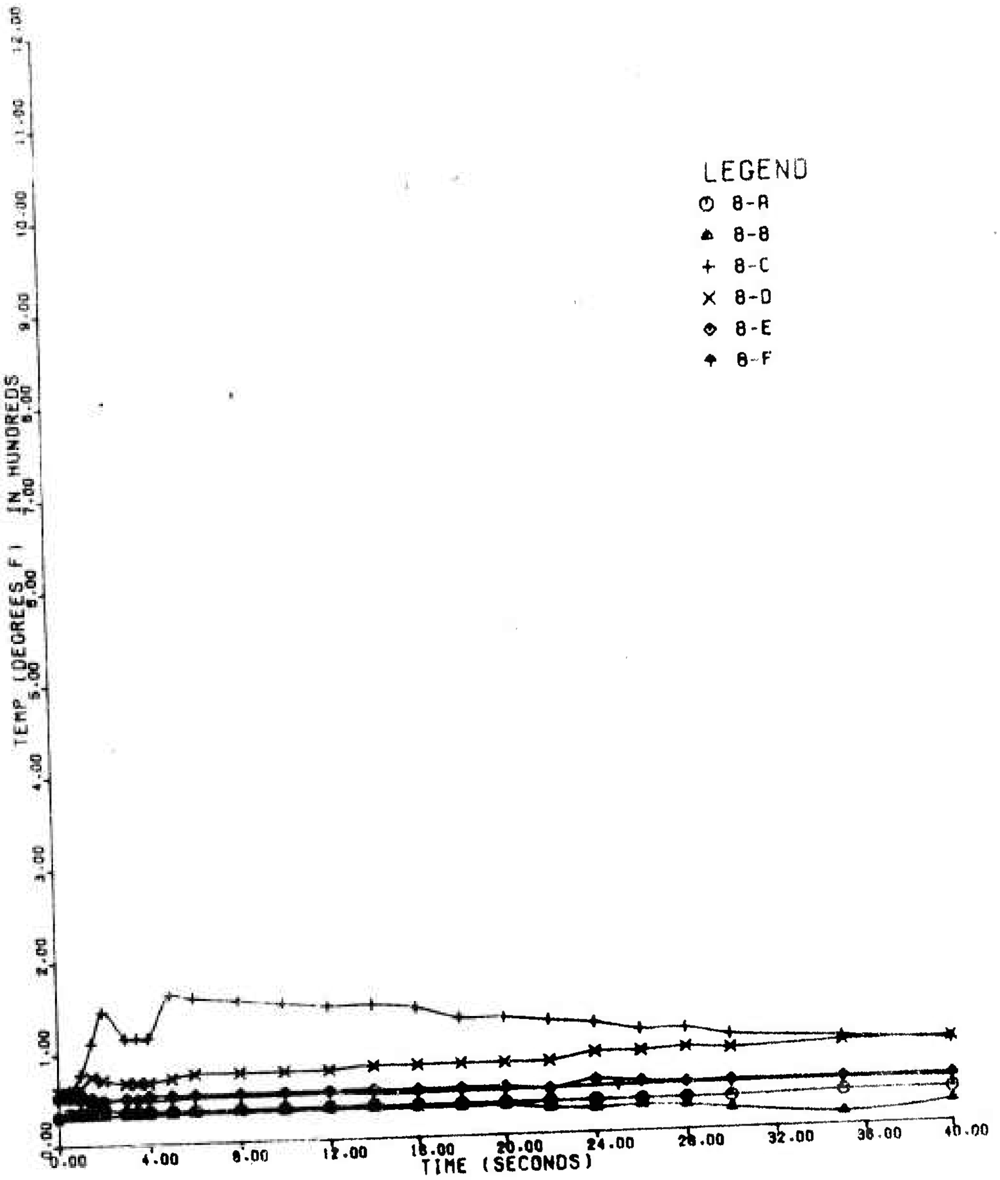

FIGURE D-33

CVA Magazine Test

No. 5

25 October 1973

APPENDIX E

PHOTOGRAPHS OF MAGAZINE INSTRUMENTATION, ORDNANCE CONFIGURATION, AND RESULTS OF MOTOR IGNITION

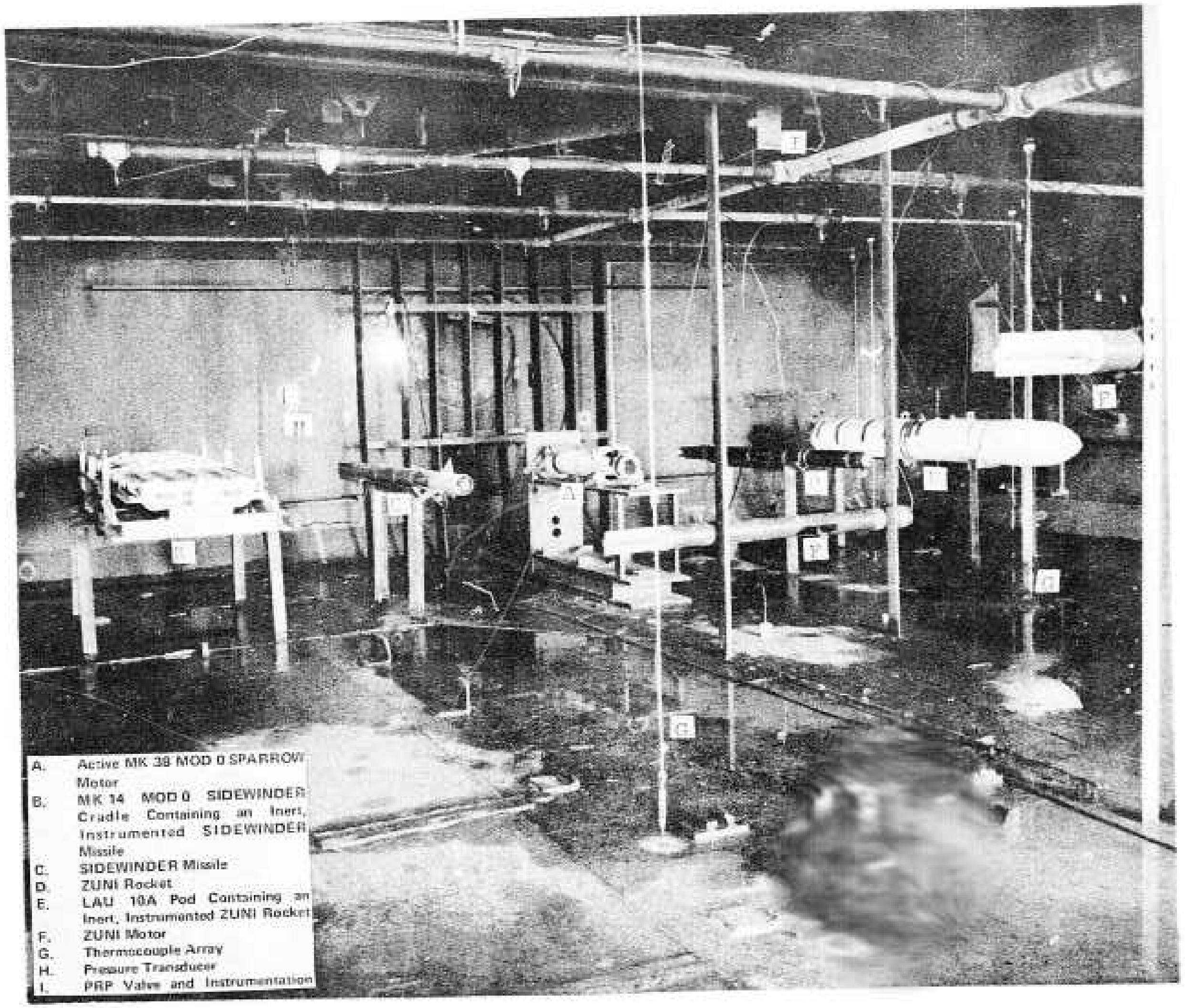

FIGURE E-1

Magazine Instrumentation and Ordnance Configuration

Test No. 3

21 September 1973

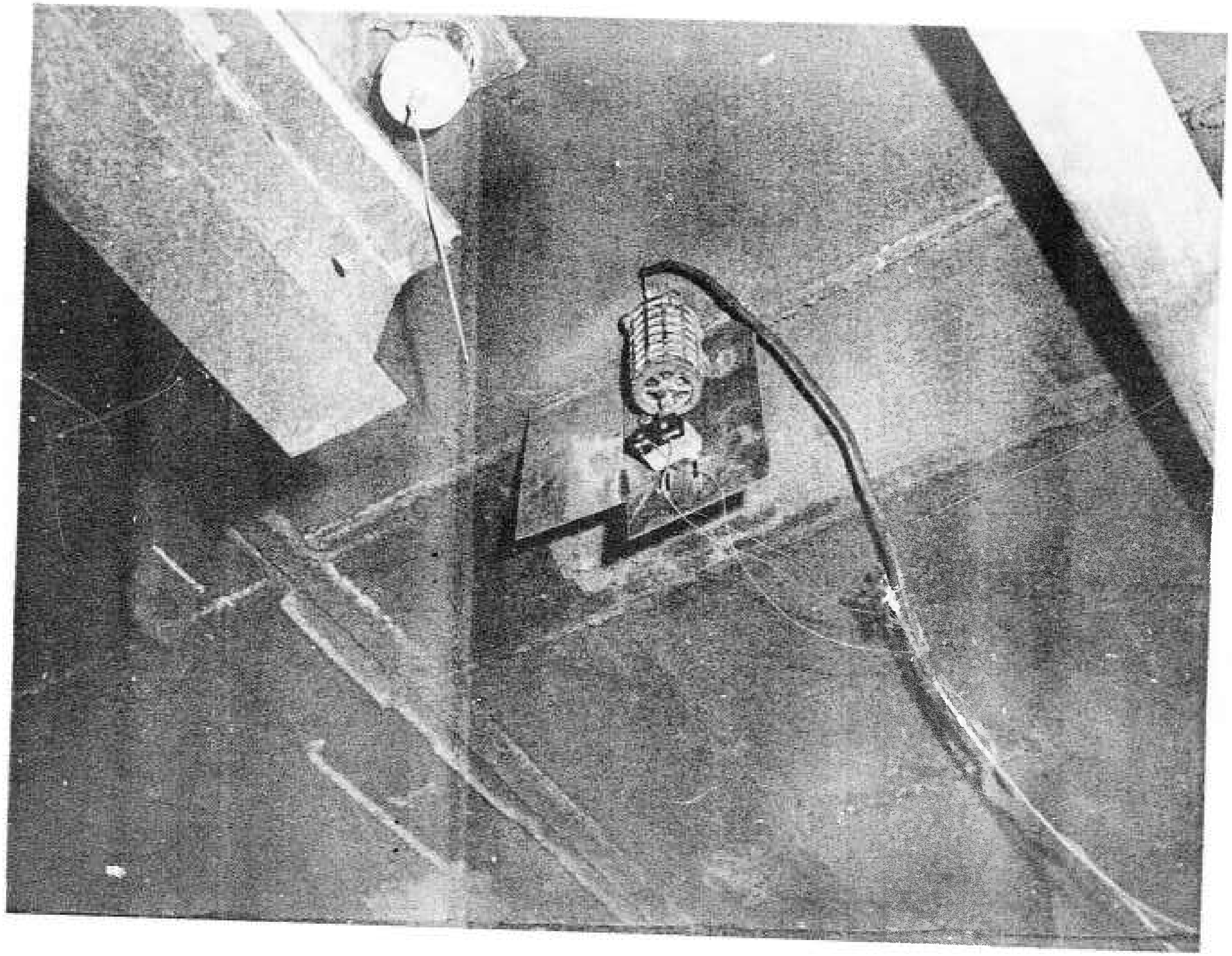

FIGURE E-2

Sylphon Detector With Micro-Switch Instrumentation

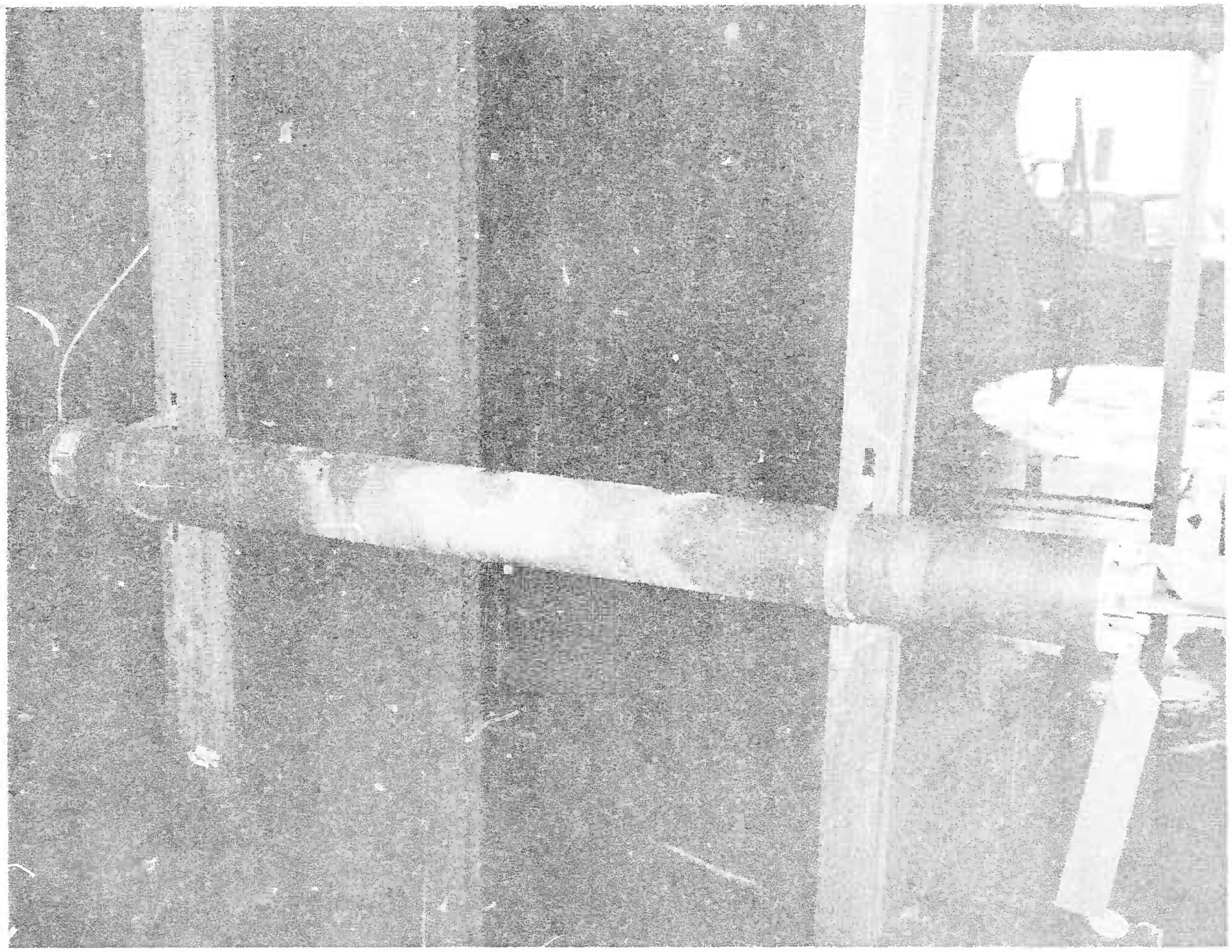

FIGURE E-3

ZUNI Motor No. 1 in Exhaust Stream of Active SPARROW MK 38 MOD 0 Motor

Test No. 3 21 September 1973

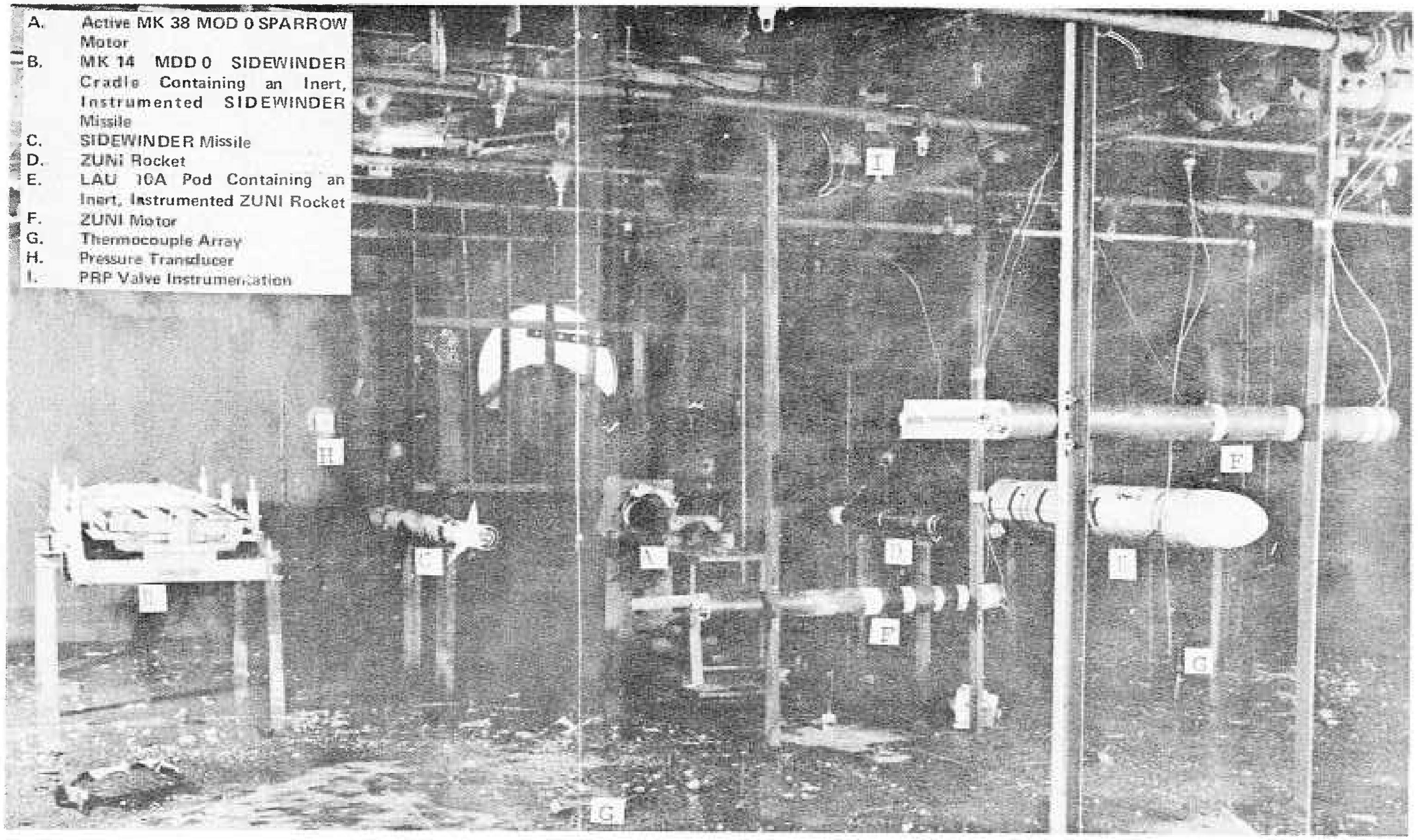

FIGURE E-4

Test Magazine After Rupture of SPARROW MK 38 MOD 0 Motor

Test No. 4 — 27 September 1973

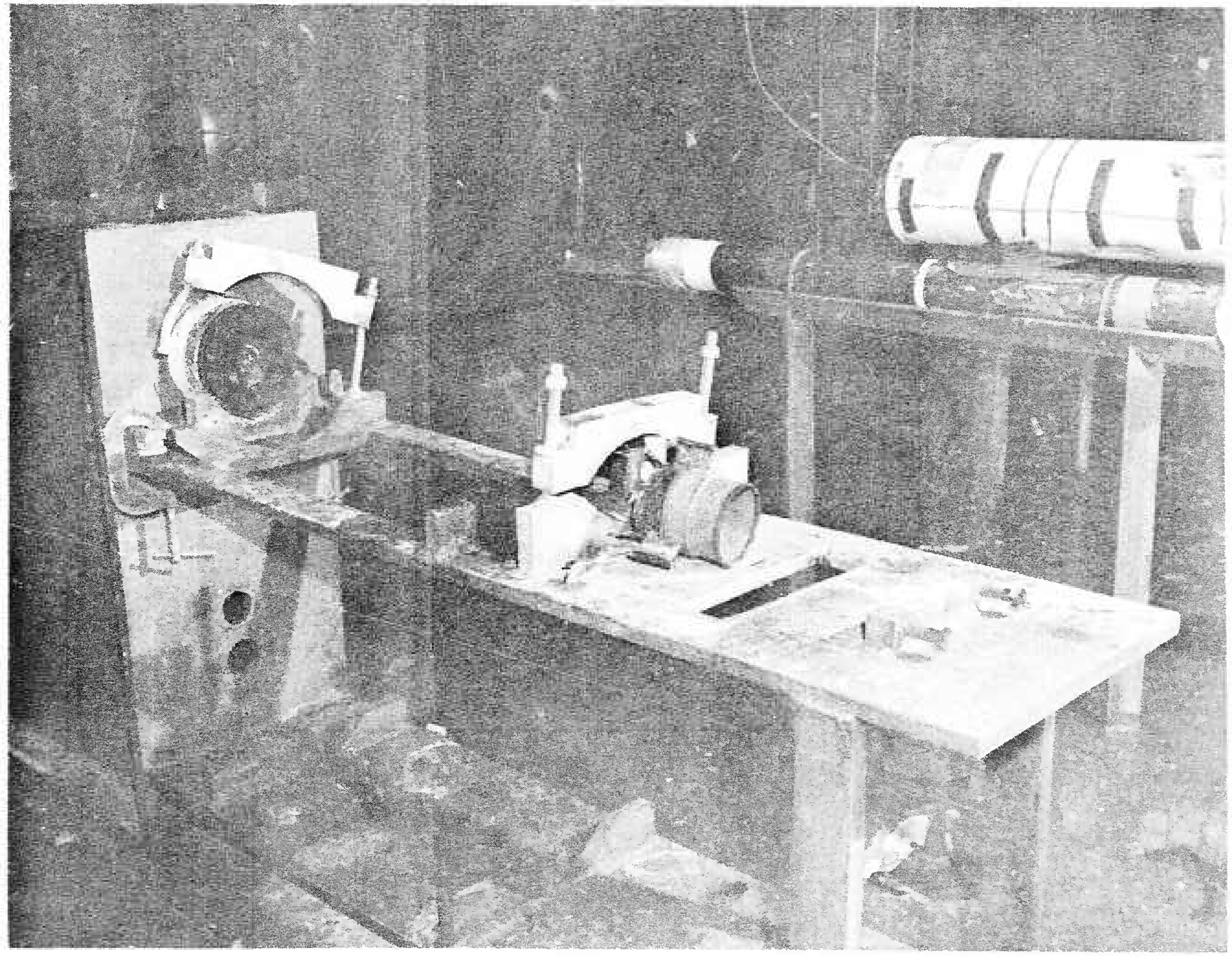

FIGURE E-5

Remains of SPARROW MK 38 MOD 0 Motor on Static Thrust Stand After Motor Rupture
Test No. 4 — 27 September 1973

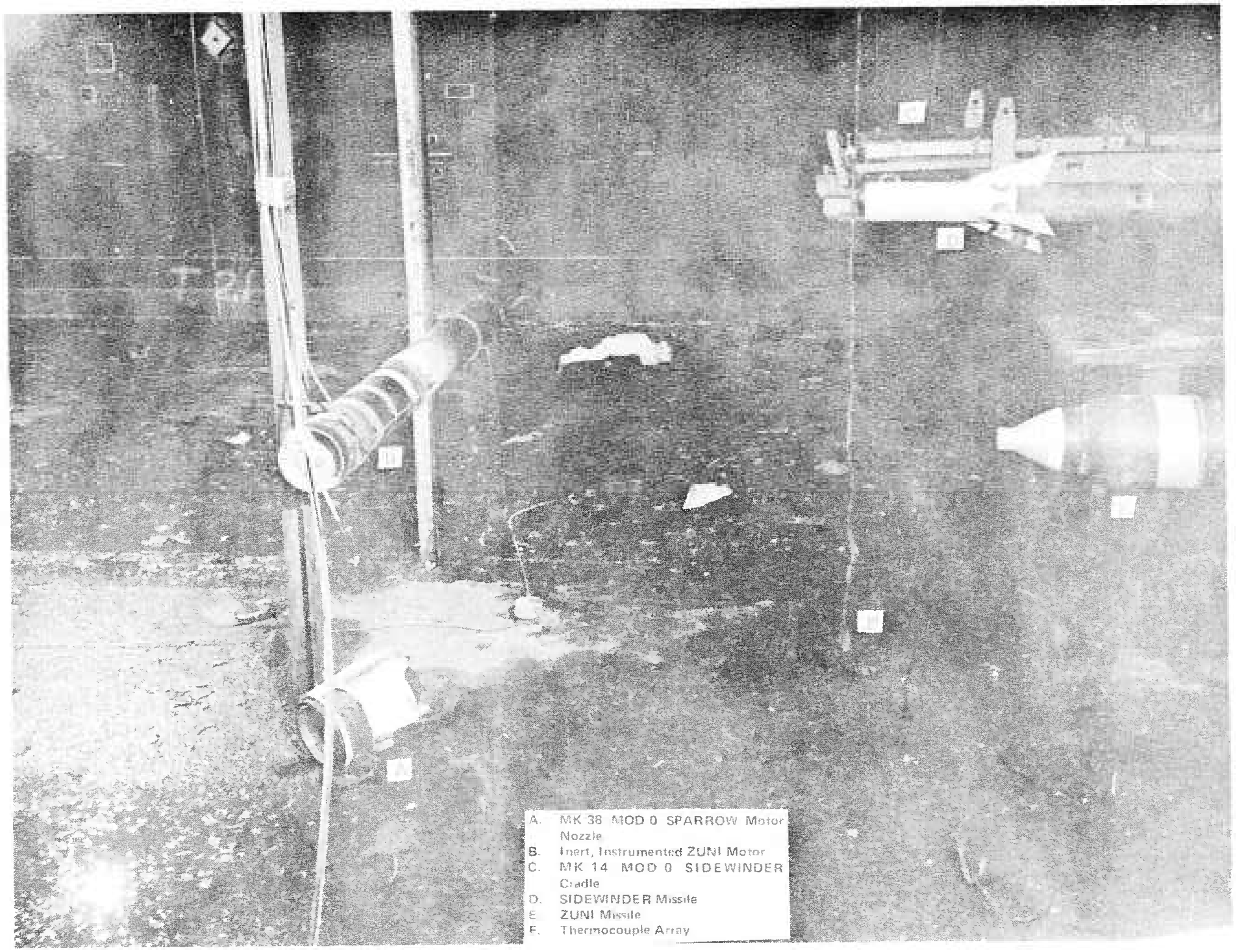

FIGURE E-6

View of Test Magazine After Rupture of SPARROW MK 38 MOD 0 Motor

Test No. 4 **27 September 1973**

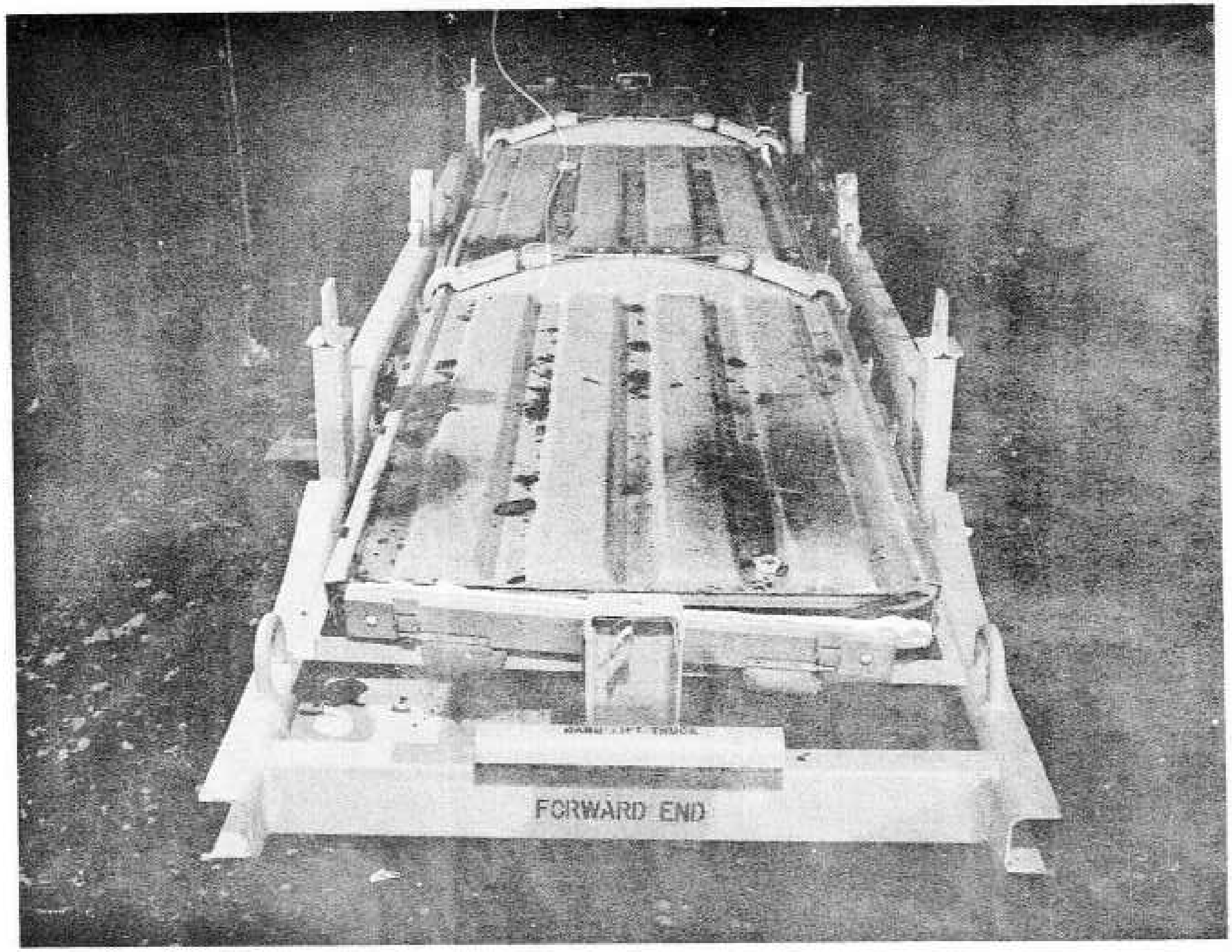

FIGURE E-7

MK 14 MOD 0 SIDEWINDER Cradle After Rupture of SPARROW MK 38 MOD 0 Motor

Test No. 4 27 September 1973

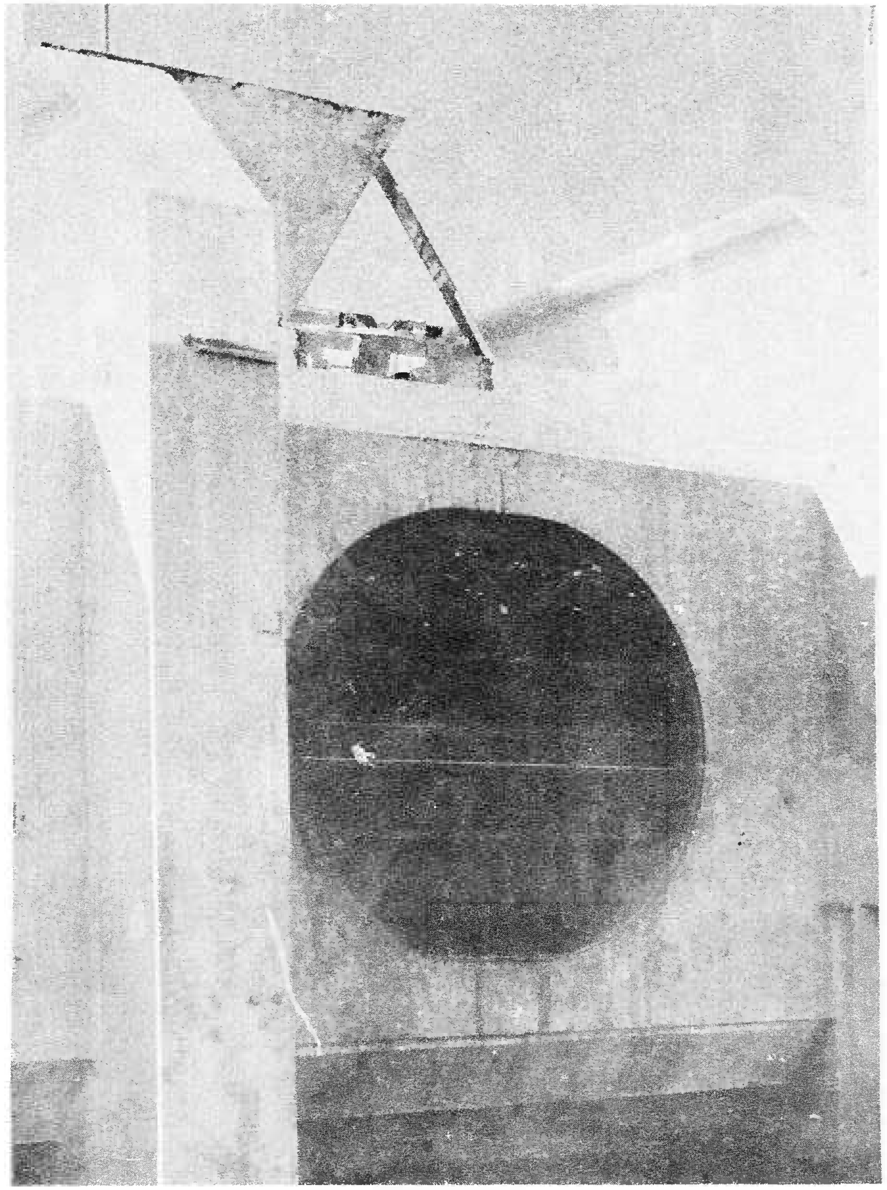

FIGURE E-8

Door of Test Magazine Minus Blow-Out Vents and Mounting Ring

Test No. 5

25 October 1973

APPENDIX F

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

SPARROW MK 38 MOD 0 or MOD 1 motors were ignited in three tests in an instrumental 15,300 cubic-foot magazine under conditions that would simulate accidental ignition of the motor under shipboard service conditions using the wet or dry sprinkler system as the damage control mechanism. The results provided a detailed temperature and pressure profile in the magazine; and thermal characteristics for bare, inert, instrumented ZUNI motors, bare, inert, instrumented, all-up configuration of SIDEWINDER and ZUNI missiles,

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and inert, instrumented, containerized, all-up SIDEWINDER and ZUNI missiles located in the magazine.

Temperatures and pressures within the magazine reached a peak of 1200°F and 19 psig. External and internal temperatures for the instrumented, inert ordnance peaked at 915°F and 460°F, respectively. Data from these tests will assist in evaluating the relative effectiveness of the wet vs dry sprinkler system in preventing chain reaction of ordnance in deep-stowage missile magazines during motor burn, and in evaluating thermal systems designed for explosive ordnance.